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Trafficability Study for the Soviet Nuclear Icebreaker ROSSIA Voyage to the North Pole: July 31 to August 15, 1990

Sponsored by: Transportation Development Centre,
Policy and Coordination Group, Transport Canada

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16. Abstract

This report presents findings of a trafficability study conducted by Norland Science and Engineering Ltd. on board the 55 000 kW Soviet nuclear icebreaker ROSSIA during her August 1990 voyage from Murmansk, USSR, to the North Pole.

The report provides detailed descriptions of the vessel ROSSIA, Soviet ice navigation techniques and technologies, ice and environmental conditions encountered during the voyage and related vessel performance.

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16. Résumé

Le rapport donne les résultats de l'étude de traficabilité menée par Norland Science and Engineering Ltd. à bord du brise-glace nucléaire soviétique ROSSIA, d'une puissance de 55 000 kW, durant son périple d'août 1990 entre le port de Mourmansk (U.R.S.S.) et le Pôle Nord.

Le rapport donne aussi des informations sur les conditions glacielles arctiques et les conditions environnementales observées, sur les techniques soviétiques de navigation dans les glaces et sur le brise-glace ROSSIA et son comportement dans les glaces.

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Summary

This report presents the findings of a trafficability study conducted by Norland Science and Engineering Ltd. on board the 55 000 kW Soviet nuclear icebreaker ROSSIA during her August, 1990 voyage from Murmansk, USSR, to the North Pole.

ROSSIA departed Murmansk on July 31, 1990. The route outbound crossed the Barents and Kara Seas, and followed the Siberian coast through the Wilkitski Strait into the Laptev Sea before turning northward along the east coast of Severnaya Zemlya. The North Pole was reached on August 8 after following a more or less direct path along 95^0 east longitude. The return route followed 65^0 east longitude southward to the Franz Joseph archipelago, returning across the Barents Sea to arrive back in Murmansk on August 15.

Throughout the voyage, data were collected describing: Arctic ocean ice and environmental conditions north of the USSR; Soviet ice navigation techniques and technologies; the nuclear icebreaker ROSSIA; and the icebreaking performance of ROSSIA.

Ship Particulars

ROSSIA is a triple screw, 55 000 kW turbo-electric icebreaker having gross registered tonnage of 20 664 tonnes, an overall length of 150 m, beam of 30 m and draft of 11 m. Primary power is provided by two nuclear reactors. Eight heat exchangers convert heat from a high pressure hot water loop to a steam loop. Two 27.5 MW steam turbines operating at 3 600 rpm each power three 780 V, 6 phase AC generators. Power is converted to DC for the three 1 000 V, 17.6 MW dual armature DC motors, one for each propeller screw. The propellers are each 5 m in diameter.

The vessel was constructed with four special icebreaking features as follows:

- air bubbler system
- trim and roll system
- shell plate heating system
- ice piece deflectors (hull appendages)

Of these features only the air bubbler system is used operationally. The bubblers, which may draw as much as 10% of total ship power, are considered to be a very important contributor to the vessel's icebreaking capability.

The trim and roll system was not found to be of much use in normal operations. However, it is useful for adjusting ships trim during stem-to-stern towing. The shell plating heating system has never worked, and the ice piece deflectors were removed from the hull structure after they were found to be ineffective in clearing away broken ice pieces, and were easily damaged.

In open water, ROSSIA was able to maintain a cruising speed of 19 knots at 55% of total reactor power. The results of earlier sea trials are presented in the report, and include data for turning circles, crash stops, draft changes, etc.

Ice Information and Navigation

The primary sources of data used by the Soviets to produce ice analysis and ice forecast information products are low resolution (4 km) visual, infra-red (NOAA, METEOR) and active microwave (Side Looking Airborne Radar - SLAR) satellite sensors, as well as higher resolution (30 m) airborne SLAR and airborne visual reconnaissance.

Technology for delivering ice forecast products to ships at sea is not well developed. ROSSIA did not carry any means of receiving satellite data directly, nor of receiving airborne SLAR data (other than a physical delivery of hardcopy imagery to the ship). The ship was not equipped with a marine facsimile receiver, and therefore the only forecast/analysis products received were those delivered from a shore station in one helicopter trip.

The main ice navigation support tools were the two Visual Flight Rule (VFR) helicopters carried on board. Prior to entering the multi-year pack ice, long range reconnaissance missions lasting sometimes several hours were conducted, from which observed charts were produced. The Soviets used their own coding methods for annotating ice conditions, which were different from the internationally recognized World Meteorological Organization (WMO) egg code.

Once in the heavy pack ice, the aircraft were flown on a virtually continuous basis to search out and guide the vessel through the lightest possible ice conditions (subject to weather, refuelling, crew changes etc.). This technique was seen to be very effective in routing the vessel around the perimeter of vast and giant floes, through leads and smaller floe sizes.

Ice Conditions and Vessel Performance

Transit particulars, meteorological particulars, ice conditions, tactical navigation and vessel performance were documented on a 24-hour basis while operating in ice-infested waters. Data were logged using a personal computer and a relational data base software package, which was used to analyze trafficability data.

Shipboard observations of ice edges and total ice concentrations corresponded well with passive microwave satellite data products produced by the Centre for Research in Earth and Space Science (CRESS), within the limits of the sensor resolution (25 km).

The main pack ice lay north of 80^0 N, and comprised multi-year ice in a state of initial decay, with extensive surface melt but no thaw holes, except in the more southerly regions. The larger (vast and giant) and probably heavier floes were avoided, with the result that from the shipboard perspective, ice conditions were consistently 9 tenths total coverage, increasing to

9+ tenths during extended periods of light to moderate pressure experienced during the northbound leg.

Most of the ice transitted by the vessel was relatively young, perhaps only a few years old, as indicated by relatively unweathered ridges and rubble, and the absence of well defined surface drainage patterns. Ice thickness data derived from calibrated downward-looking photography averaged in the range 159 to 209 cm for level, undeformed ice floes. Ice properties data collected at the North Pole found the internal temperature of one level ice floe to lie in the range -0.1 to -0.9°C.

Average speed made good varied from a high of 15.0 knots in 6-9 tenths ice to a low of 8.1 knots in 9+ tenths, moderately pressured ice. Some ramming was occasionally required to loosen the ship, particularly when pressure was being experienced. However, the typical reversing distance was only about 100 m and impact speed was therefore relatively slow, usually around 4 knots. This was most often sufficient to "free" the vessel, and she would continue to accelerate through the ram.

Financial partners in the project included: Norland Science & Engineering Ltd., Canarctic Shipping Company Limited; the Transportation Development Centre, Transport Canada; the National Research Council of Canada; and the Centre for Research in Experimental Space Science of the Atmospheric Environment Service, Environment Canada.

SOMMAIRE

Le rapport donne les résultats de l'étude de traficabilité menée par Norland Science and Engineering Ltd. à bord du brise-glace nucléaire soviétique ROSSIA durant son périple d'août 1990 entre le port de Mourmansk (U.R.S.S.) et le Pôle Nord.

Ayant appareillé le 31 juillet 1990, le brise-glace a effectué le parcours suivant: mers de Barents et de Kara, mer de Laptev après avoir traversé le détroit de Vilkitskogo, direction nord à l'est de la Severnaïa Zemlia (Terre du Nord) et trajectoire plus ou moins directe le long du 95ie méridien est jusqu'au Pôle Nord atteint le 8 août. Pour le retour, le brise-glace, descendant le 65ie méridien est jusqu'à l'archipel François-Joseph, a traversé la mer de Barents pour revenir à Mourmansk le 15 août.

Tout au long du périple, des informations ont été rassemblées sur les conditions glacielles arctiques et les conditions environnementales au nord de l'Union Soviétique, sur les techniques soviétiques de navigation dans les glaces et sur le brise-glace ROSSIA et son comportement dans les glaces.

Description du brise-glace

Le ROSSIA est un brise-glace à trois hélices à propulsion turbo-électrique d'une puissance totale de 55 000 kW. Son tonnage brut est de 20 664 tonnes et sa longueur hors tout est de 150 m; il a un bau de 30 m et un tirant d'eau de 11 m. Deux réacteurs nucléaires produisent l'énergie primaire. Huit échangeurs de chaleur transfèrent l'énergie thermique d'un circuit à eau chaude sous pression à un circuit vapeur qui alimente deux turbines à vapeur de 27,5 MW tournant à 3 600 tr/min et entraînant, chacune, trois alternateurs 780 V, 6 phases. Le courant alternatif redressé alimente trois moteurs c.c. de 17,6 MW, 1000 V, à double induit, soit un moteur par hélice. Celles-ci ont un diamètre de 5 m.

Le brise-glace possède les dispositifs suivants :

- système à bulles d'air
- système de tangage et de roulis
- chauffage du bordé extérieur
- déflecteurs de glace (appendices de coque)

Seul le système à bulles d'air a été utilisé en service. Ce système, qui peut consommer jusqu'à 10 p. 100 de la puissance totale installée, est considéré une pièce maîtresse de l'équipement du brise-glace. Le système de tangage et de roulis n'a pas été d'une grande utilité en service normal; mais il est utile pour le réglage de l'assiette durant une opération de remorquage en contact. Le chauffage du bordé extérieur n'a jamais bien fonctionné, tandis que les déflecteurs ont dû être enlevés lorsqu'on s'est aperçu qu'ils étaient non seulement inefficaces, mais aussi très vulnérables.

En eau libre, le brise-glace a pu avancer à une vitesse soutenue de 19 noeuds à un régime égal à 55 p. 100 de sa puissance totale. Des résultats d'essais précédents en mer sont inclus, comprenant des données sur les caractéristiques de giration, d'arrêt d'urgence, de correction d'assiette, etc.

Information sur les glaces et navigation dans les glaces

Pour obtenir des prévisions sur les conditions glacielles, les Soviétiques utilisent les satellites pour obtenir une imagerie faible résolution (4 km) provenant de capteurs passifs dans le spectre visible et infrarouge (NOAA, METEOR) et de capteurs actifs à hyperfréquences (radars à visée latérale). Pour une plus haute résolution (30 m) un radar aéroporté à visée latérale est utilisé, en plus d'observations directes par aéronef.

Leur technologie pour transmettre les prévisions aux navires en mer n'est pas très avancée. Le brise-glace ROSSIA ne disposait d'aucun moyen pour recevoir directement l'information satellitaire ni, non plus, l'information par radar aéroporté. Il n'en recevait que des copies papier amenées à bord par un hélicoptère. Il ne disposait pas, non plus, de récepteur de télécopie; la seule information et les seules prévisions à bord venaient d'une station terrienne qui les lui avaient livrées par hélicoptère.

La principale aide à la navigation dans les glaces était assurée par deux hélicoptères embarqués volant en régime de vol à vue. Avant de pénétrer dans la banquise le ROSSIA lançait des missions d'observation de longue portée pouvant durer plusieurs heures et d'où étaient tirées les cartes de glace. Les annotations utilisées par les Soviétiques diffèrent du code mis au point par l'Organisation météorologique mondiale.

Dans la banquise, le navire utilisait constamment les hélicoptères afin d'identifier les zones où les conditions glacielles étaient les moins sévères, sauf si les conditions météo, les besoins de ravitaillement en carburant ou les changements de quarts ne l'interdisaient. Cette façon de procéder a été très efficace car elle permettait au navire de contourner les bancs géants, de suivre les chenaux de séparation et de n'attaquer que les bancs les plus petits.

Conditions glacielles et comportement du navire

Les circonstances du parcours, les données météorologiques, les conditions glacielles, les choix de navigation tactique et les performances du navire étaient enregistrés systématiquement et sans interruption lorsque le navire se trouvait dans des zones chargées de glaces. Les données étaient stockées dans la mémoire d'un ordinateur et analysées grâce à un logiciel de base de données relationnelles.

Les observations faites à bord, relatives aux limites des glaces et aux concentrations glacielles totales, concordaient bien avec les informations transmises par les détecteurs passifs à hyperfréquences utilisés par le Centre de recherche pour les sciences de la terre et de l'espace (CRESS) d'Environnement Canada, dans les limites de la résolution du capteur utilisé (25 km).

La principale banquise se trouvait au nord du 80ie parallèle de latitude nord. Elle était composée de glaces pluri annuelles commençant à pourrir, ayant à sa surface de larges mares mais ne comportant pas de trous de dégel, sauf dans les parties les plus au sud. Etant donné que les bancs les plus grands et, probablement, les plus épais avaient pu être évités, la navigation s'est faite presque toujours dans des conditions de concentration totale de 9/10. Une concentration plus forte a été observée dans le parcours vers le nord lorsque des glaces, sous pression faible et moyenne, ont été rencontrées durant de longs moments.

La plupart des glaces observées étaient relativement jeunes, quelques années tout au plus, si l'on en juge par la présence de crêtes et de blocs à peine altérés, ainsi que l'absence de réseaux de drainage bien définis. Quant à l'épaisseur moyenne des glaces mesurée à partir de photographies plongeantes étalonnées, elle s'établissait entre 159 et 209 cm dans le cas des bancs uniformes. Les mesures visant à déterminer les propriétés des glaces au Pôle Nord ont révélé une température intérieure entre - 0,1 et - 0,9 C, dans le cas d'un banc uniforme.

La vitesse moyenne corrigée a fluctué entre un maximum de 15 noeuds dans des glaces de concentration de 6 à 9/10 et un minimum de 8,1 noeuds dans des glaces de 9+/10, de pression moyenne. Il fallait de temps à autre éperonner la glace pour dégager le navire, notamment dans des glaces sous pression. Cependant, le recul n'était que d'une centaine de mètres, la vitesse au moment de l'impact étant de ce fait plutôt faible, généralement autour de 4 noeuds. Il n'en fallait pas plus pour dégager le navire qui continuait à accélérer.

Ce projet a été financé par les partenaires suivants : Canarctic Shipping Company Limited; Centre de développement des transports, Transports Canada; Conseil national de recherches du Canada; Centre de recherche pour les sciences de la terre et de l'espace, du Service de l'environnement atmosphérique, Environnement Canada et Norland Science and Engineering Ltd.

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Only a few short years ago, Western scientific participation in a voyage by a Soviet nuclear icebreaker to the geographic North Pole would have seemed a very remote possibility. Today, in the new spirit of East-West cooperation, this opportunity and similar opportunities in many other sectors have become reality. For the invitation to join ROSSIA on her polar voyage, I am very grateful to three individuals who made the voyage possible: Mr. Masutkin, Vice President of the Murmansk Shipping Company (MSC), operators of ROSSIA; Mr. Gunter Schultz, President of Polar-Shiffahrts Consulting GmbH of Germany, commercial agents for the voyage; and Mr. Sergey V. Karpekin, Deputy Director of International Cooperation for the Arctic and Antarctic Research Institute (AARI) in Leningrad, who acted as intermediary in contract negotiations.

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The Soviet Nuclear Powered Icebreaker ROSSIA
Breaking Decayed First-Year Ice in the Kara Sea, USSR
August 4, 1990

Trafficability Study for the Soviet Nuclear Icebreaker ROSSIA Voyage to the North Pole, July 31 to August 15, 1990

1.0 INTRODUCTION

This report presents data collected on board the Soviet nuclear powered icebreaker ROSSIA during a recent voyage to the geographic North Pole. The voyage took place between July 31 and August 15, 1990, departing from the Barents Sea port of Murmansk, USSR. Data collected describe ice and environmental conditions encountered throughout the voyage, as well as vessel navigation and performance.

The ROSSIA is a 55 000 kW (75 000 hp) icebreaker of the "ARCTICA" class. The vessel was built at the Baltic Sergo Ordszenikidze Shipyard near Leningrad and officially launched in November 1983. It was not commissioned for Arctic service however, until late 1984 or 1985. It is operated by the Murmansk Shipping Company (MSC), as is the entire Soviet nuclear icebreaker fleet. Gross registered tonnage is 20 664 tonnes, overall length is 150 m, maximum beam is 30 m, and design draft is 11 m. A summary listing of the current and proposed Soviet nuclear icebreaker fleet is provided in **Table 1.1**.

1.1 Background

Before the ROSSIA voyage only two surface vessels had probed deep into the Arctic basin, both Soviet nuclear powered icebreakers. The ARCTICA sailed to the North Pole in 1977 (Brigham, 1985). The following year SIBIR escorted the cargo vessel KAPITAN MYSHEVSKY on an early season, high latitude trans-polar crossing from Murmansk to the Chukchi Sea. This voyage took place over the period May 25 to June 13, 1978, and brought the vessels close to the North Pole (Mikhailichenko, 1986). We are not aware of any information on ice conditions or vessel operations having been published in the open literature for either of these voyages.

The purpose of the ROSSIA voyage was to carry Western tourists on a passenger cruise to the North Pole, via the western section of the North-East Passage. The historic voyage was made possible by a tripartite agreement between the Murmansk Shipping Company, Murmansk; the Arctic and Antarctic Research Institute, Leningrad; and POLAR Schiffahrts Consulting GmbH of (West) Germany.

There is currently a great deal of interest in the West in possibilities for trans-polar shipping. The governments of Canada, USA, Germany and Sweden are all considering the possibility of icebreaker probes into the high Arctic during the early 1990s. From the Canadian perspective, the performance of ROSSIA is seen as a barometer of what the requirements might be for Canadian icebreakers to operate in similar areas north of Canada in the future. In addition, there is a commercial interest in opportunities which may arise from the anticipated opening by the Soviets of the North-East passage to foreign flag shipping. These include both merchant shipping and tourism.

Table 1.1

Current and Proposed Fleet of Soviet Nuclear Icebreakers

Class/Vessel	Year Operational	Year Decommissioned	Power (kW)	Length (m)	Beam (m)	Draft (m)	Gross Tonnage
LENIN	1959	1986 (est.)	32 000	134	28	10	19 240
ARCTICA							
/ ARCTICA	1975	-					
/ SIBIR	1976	-					
/ ROSSIA	1984/85	-	55 000	150 O.A. 136 B.P.	30 maximum 28 molded	11	20 664
/ SOVETSKIY SOYUZ	1989	-					
/ OCTOBER REVOLUTION	1991 (planned)	-					
TAYMYR							
/ TAYMYR	1989	-	38 000	149	27	8	22 000 (est.)

Source: Brigham, L.W. (1985) and this study.

With the combined support of several sponsors, sufficient funding was secured to send one engineer from Norland Science to join the cruise. ROSSIA thus became a ship of opportunity for conducting scientific research on ship operations through some of the most difficult ice conditions experienced by icebreakers.

1.2 Objectives

The primary objective of the work was to collect baseline data which could be applied in the study of:

- regional and local ice conditions
- ship navigation techniques and technologies
- icebreaking performance of ships
- ice loads on ships
- validation of spaceborne remote sensing instruments and data products

1.3 Method of Approach

Prior to embarkation, we received assurances from the Soviets that we would be permitted full access to all areas of the ship, and that the ship's helicopter would be available for charter. Although the charter rate given was quite high ($37./min), it was hoped that by sharing excursion costs with other passengers, we would be able to disembark on occasion and measure ice physical properties.

A comprehensive observation program was designed for execution while sailing in ice infested waters, which formed the basis of the project work plan (Norland, 1990). The plan identified four primary types of data to be collected:

- general transit
- environment
- navigation
- vessel performance

Table 1.2 provides a detailed listing of parameters proposed for collection under each of these categories.

We were fortunate that another passenger, Dr. Alfred Tunik of the American Bureau of Shipping, had similar interests to our own and we were able to join forces in data collection. Working in cooperation, it was possible to maintain bridge observations virtually 24 hours per day while sailing in ice.

Data collection began on August 2, 1990 with the first ice encountered. The ship's officers were quite cooperative, allowing full access to the bridge with the exception of photography near the chart table and navigation console. This cooperation was noteworthy, because it was not until our return to Murmansk that we learned that our freedoms and privileges had

Table 1.2

Documentation of ROSSIA Trafficability Parameters

		Documentation Format			
	Observation Type	IDIADS Database	Reference Diary	Video Log	Text Log
I. Transit Particulars					
- ship position (latitude and longitude)	Hourly Sample	X			
- course and speed	•	X			
- course and distance made good	•	X			
- transit mode	•	X			
- operations (downtime, escorts)	Event Basis	X	X		
- vessel draft and trim	Trim not recorded		X		
II. Environmental Particulars					
Meteorological Conditions:					
- air temperature	Hourly Sample	X			
- sea temperature	Not Available				
- winds	Hourly Sample	X			
- sea state	•	X			
- cloud cover, precipitation	•	X			
- visibility	Hourly Sample & Event Basis	X		X	
Ice Conditions:					
- types and concentrations	Hourly Average	X		X	
- floe sizes	•	X		X	
- stage of formation/decay	•	X		X	
- ridge frequency and/or rubble conc's	•	X		X	
- ice topography descriptions	Event Basis		X	X	
- snow cover, surface melt	Hourly Sample & Event Basis	X	X	X	
- leads	Event Basis		X	X	

Table 1.2 (continued)

Documentation of ROSSIA Trafficability Parameters

		Documentation Format			
	Observation Type	IDIADS Database	Reference Diary	Video Log	Text Log
Ice Conditions (continued):					
- 35 mm photography	Hourly Sample & Event Basis	X	X		
- VHS video	Hourly Sample & Event Basis	X			
- ice regime boundaries	Event Basis	X			
- ice dynamics	"		X		
- ice pressure	"	X	X	X	
- track characteristics	"		X	X	
Ice Properties:					
- thickness	Opportunity Basis				X
- temperature profile	"				X
- salinity profile	"				X
- formation (rafting)	Event Basis				X
III. Navigation Particulars					
- ice information sources	Event Basis				X
- route planning	"				X
- marine radars	Hourly Sample	X			
- manning	General				X
- manoeuvring	Event Basis		X	X	
- discrete feature encounters	"		X		
- ramming	"	X	X		
- turning circle performance	Not Available				
- escort roles	Event Basis		X		

Table 1.2 (continued)

Documentation of ROSSIA Trafficability Parameters

	Observation Type	Documentation Format			
		IDIADS Database	Reference Diary	Video Log	Text Log
IV. Performance Particulars					
- propeller shaft rpm	Hourly Sample	X			
- motor voltage and current	Not Available				
- total reactor power	Hourly Sample	X			
- propeller shaft power levels	•	X			
- thrust, other	Not Available				
- power by ice regime	Analysis				X
- propulsion/machinery	General			X	X

been granted primarily in the context of tourism, and that there had been bureaucratic reluctance to permit scientific data collection, particularly within 200 n.mi. of the Soviet coastline.

Table 1.2 indicates for each variable, the type of observation and documentation format which was employed in the data collection program. As seen from the table almost all of the proposed parameters were successfully collected. Transit particulars were recorded as indicated by the ship's instrumentation and continuous monitoring of operations. Meteorological conditions were observed and recorded at regular intervals. Pack ice conditions along the ship route were described by continuous visual estimates and photography of ice type and partial concentration, ice morphology and surface melt. The navigation process was monitored continuously, and special ship handling manoeuvres, ice information products, etc. were documented in the observation logs.

The two areas in which we would have hoped to gather more information were vessel performance and ice properties measurements. In the case of vessel performance, total reactor power, shaft speed and shaft power level settings for each of the three propellers were the only data available on the bridge. No means of recording average performance over time was available, either on the bridge or in the engine room. Shaft speed and power were therefore recorded at routine hourly intervals throughout the transit. Power level instrumentation provided data relative to the full bollard thrust condition only. These data will therefore generally be higher than true shaft power, which is a complex function of propeller and ship speeds.

In the case of ice properties data, the only opportunity to disembark the vessel and conduct on-ice work was when the ship stopped at the North Pole. During icebreaking, the helicopter was used exclusively for ice reconnaissance and permission to accompany the flights for this purpose was not granted.

As an alternative means of measuring ice thickness while the ship was underway, a procedure was developed using 35 mm and VHS video photography (these data include more than 3 hours of video and approximately 1 000 photographs). First, a location was selected along the vessel length at which point broken ice pieces regularly turned on their side during icebreaking. A fixed measure of length was marked on the railing of the lower deck above this point. Then, as part of the hourly observation routine, downward-looking photography of turning ice pieces was collected at the same location, but from a fixed position on a higher deck. Knowing the fixed distances between the camera position, the scale marker and the ice surface, it was possible to determine ice thickness from the photographs to an estimated accuracy of 20-30 cm, compatible with the natural variability in ice thickness.

In the field, data were logged on a portable computer into the Interactive Data Input, Analysis and Display System (IDIADS), a relational database program developed by Norland Science and Engineering Ltd. Entry field definitions, criteria and coding for this database are included as **Appendix A**.

1.4 Report Organization

This report is divided into seven sections, the first of which is this introduction. Section 2 provides a synopsis of the voyage, including highlights of the transit and a general description of ice conditions encountered.

Particulars of ROSSIA are provided in the third section, including principal characteristics and layout, details of the propulsion system and a description of the various special icebreaking features. Techniques and technologies employed by the Soviets for ice navigation, including ice information available on board the vessel during the North Pole voyage, is discussed in section 4.

Section 5 presents trafficability data collected during the voyage, including ice, environmental and ship performance particulars. The section presents the results of an analysis of these data in terms of characteristic ice regimes. Conclusions are provided in the sixth section, with references listed in the seventh.

The report is supported by five appendices. Appendix A provides a listing of the entry field definitions, criteria and coding used in the IDIADS trafficability database. The contents of the database are included in Appendix B as hardcopy in the form of four tables. Appendix C presents the VHS video log for the summary tape, compiled from over 7 hours of original material and supplied with this report under separate cover. The 35 mm slide photographs reside under separate cover as Appendix D, and are available for viewing by project sponsors on request. A series of fourteen data tables and accompanying photographic reproductions which describe the fourteen ice regimes analyzed in Section 5 are included as Appendix E.

2.0 VOYAGE SYNOPSIS

In addition to her normal complement of 139 officers and crew, approximately 55 supernumeraries accompanied ROSSIA for the North Pole voyage. These included 25 European and American tourist passengers (3 of these were working scientists), 5 officials of the Murmansk Shipping Company, 12 European and Russian media representatives, some 10 support staff, and a number of guests by special invitation of the MSC including Mr. Peter Wilkniss, Director of Administration for the American National Science Foundation, and Mr. Sergey Karpekin, Deputy Director of Foreign Relations for the AARI.

The group of passengers met at Helsinki airport on Monday, July 30 and flew on to Murmansk via Rovaniemi, Finland without incident. Our cargo shipment of ice properties measurement equipment was cleared through Soviet customs as passenger baggage. No difficulties were encountered either entering or leaving the USSR. Transportation to the ship was by bus, with a brief tour of Murmansk en route.

The port city of Murmansk ($68^0$59'N, $33^0$03'E) is located on the eastern shores of the Kola Inlet, about 40 km from the open sea. The population of about 400 000 inhabitants is largely employed in the commercial fishery and the large naval base located further down the Inlet towards the sea. Kola Inlet is ice free most of the year (minimum water temperature is about 4^0C) except for thin shorefast ice which appears at the port during the January to March period. Ice also appears for a few days every May, when local rivers break up and flush out (Sailing Directions, 1984). The open water has a tendency to temper the local climate, and above freezing temperatures are not uncommon in mid winter. Winter fog caused by the open water is a frequent navigational problem. **Plate 2-1** shows a view south over the Murmansk port facilities, taken from a local mountain top.

ROSSIA departed Murmansk at 0725 GMT (1125 local time) July 31, 1990. For the next 36 hours the ship sailed through open water down the Kola Fjord and across the Barents Sea west of Novaya Zemlya Island. The plan was to pass south of the Nordland Islands, to allow the passengers to take in the scenery of the area. The ship's track is plotted on the site map of **Figure 2-1**. Strips and patches of decayed first-year ice were encountered at the northern end of the island, and the route turned south towards the north coast of the Taymyr Peninsula in order to avoid higher ice concentrations in the north-east Kara Sea. Along this coast ice concentrations were typically 2-4 tenths decayed first-year.

It was in this area that ROSSIA joined up for a short period with a convoy of ships heading eastbound. The convoy consisted of two other nuclear icebreakers: the SOVETSKIY SOYUZ, another of the ARCTICA class ships (see **Plate 2-2**) and the recently commissioned TAYMYR, a 38 000 kW, 8 m draft vessel (see **Plate 2-3**). One diesel electric icebreaker, the MURMANSK (see **Plate 2-4**) completed the complement of icebreakers escorting the general cargo vessel M/V TOLJA KOMAR (see **Plate 2-5**). The convoy, which had been standing by awaiting the arrival of ROSSIA, was clearly arranged for the benefit of ROSSIA's passengers.

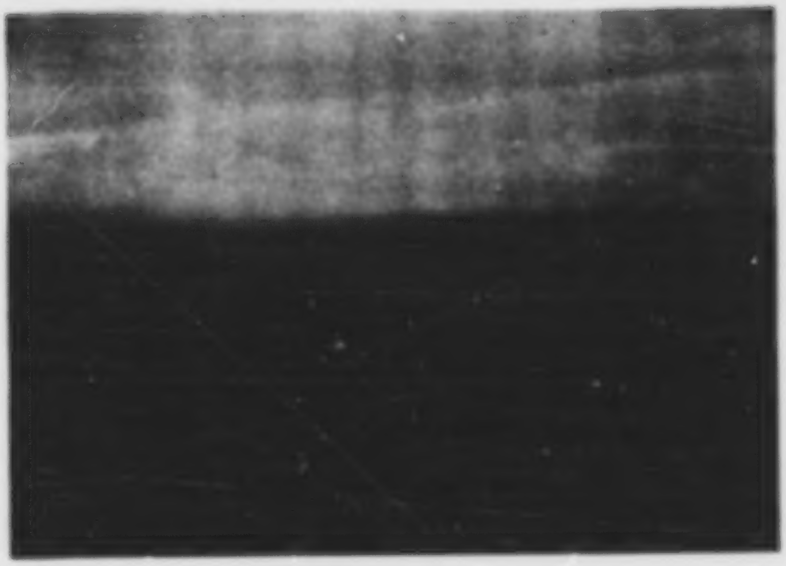


Plate 2-1 View South Over the Murmansk Port Facilities
July 30, 1990

Plate 2-2 The ARCTICA Class Nuclear Icebreaker SOVETSKIY SOYUZ
Kara Sea - August 2, 1990

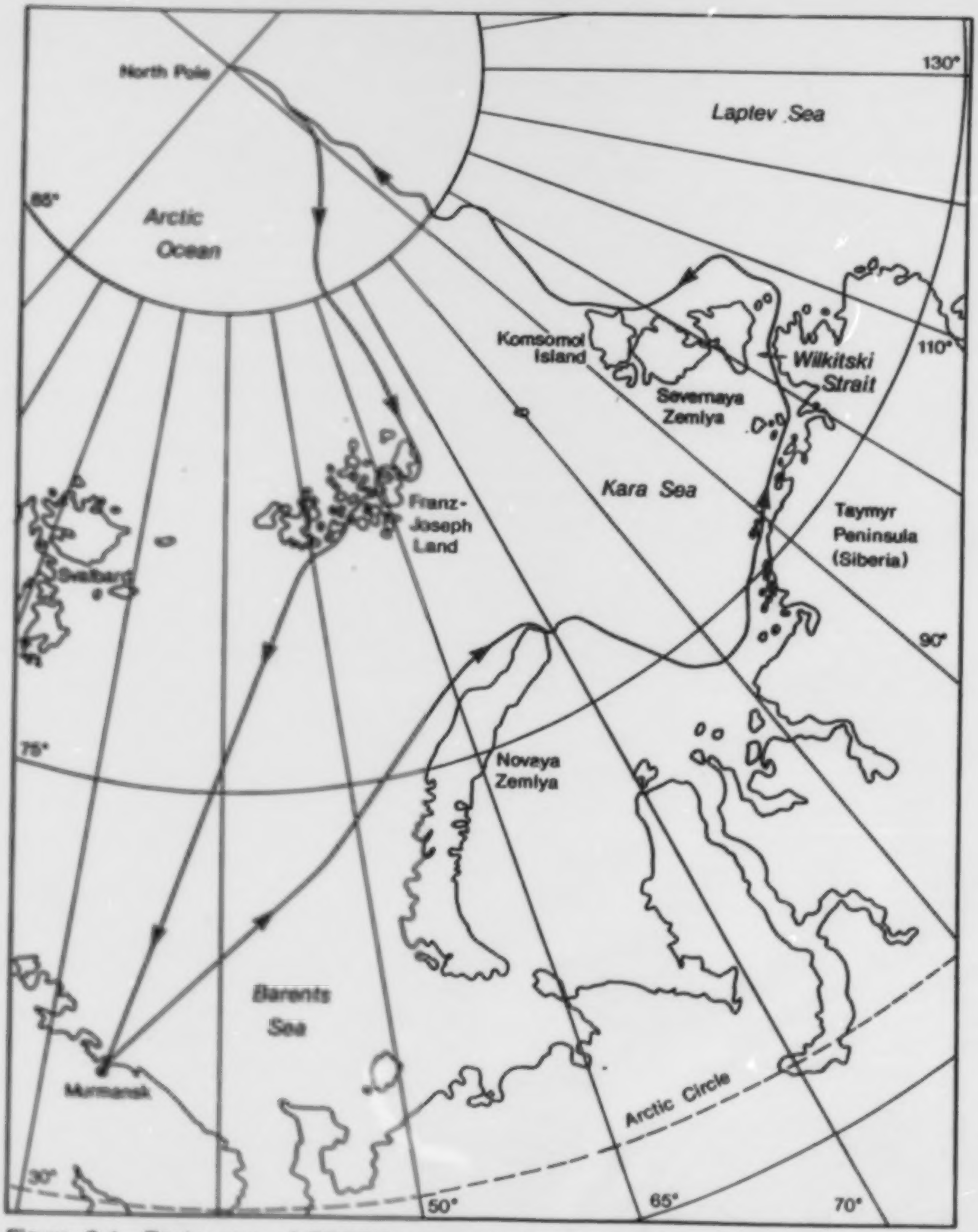

North Pole
130°
Laptev Sea
85°
Arctic Ocean
Komsomol Island
110°
Wilkitski Strait
Severnaya Zemlya
Kara Sea
Franz-Joseph Land
Taymyr Peninsula (Siberia)
Svalbard
90°
75°
Novaya Zemlya
Barents Sea
Murmansk
Arctic Circle
30°
50°
65°
70°

Figure 2-1 Route map of ROSSIA voyage to the North Pole. July 31 - August 15, 1990

Plate 2-3 The Shallow-Draft Nuclear Icebreaker TAYMYR
Kara Sea - August 2, 1990

Plate 2-4 The Diesel Electric Icebreaker MURMANSK
Kara Sea - August 3, 1990

Plate 2-5 The General Cargo Vessel M/V TOLJA KOMAR Under Escort in the Kara Sea - August 3, 1990

Plate 2-6 The Nuclear Icebreaker ARCTICA Kara Sea - August 4, 1990

ROSSIA soon departed the slower moving convoy and proceeded through the consolidated but much decayed first-year ice which lay between the Taymyr Peninsula and the Nordland Islands. The icebreaker ARCTICA, travelling in the opposite direction, was met the next day (August 4; see **Plate 2-6**). ROSSIA passed through into the western Laptev Sea later that day, and a series of large leads adjacent to the remaining shorefast ice was followed along the east coast of the Nordland Islnnds before entering the multi-year pack ice.

Virtually all the ice encountered north of 80^0 North was relatively young multi-year ice in small, medium and big floe sizes. Very few observations of older multi-year ice were made. There were almost no hummocks - the original ice blocks forming ridges and rubble were clearly evident, if somewhat weathered in the case of the apparent third year ice. Melt pond drainage patterns were not usually well developed.

The absence of older multi-year ice is attributed to the fact that almost all of the larger, possibly much older and heavier floes were rounded with the aid of virtually continuous short and medium range (15-20 n.mi.) helicopter reconnaissance support. Although vast and giant multi-year floes could often be seen one or two miles to either side, conditions actually transitted by the vessel were consistently 9/10 small and medium floe multi-year ice ranging from 1.5 to 3.5m (up to about 5m maximum) level thickness. Thicknesses over 2.5m were often seen to be the result of rafting, evident visually from the interfaces which could be seen as the ice turned on its side during icebreaking. Ridging and rubble varied typically from 10-25% of total ice cover, with sail heights usually in the 2-4m range. Meltpond coverage ranged from 5-10% at lower latitudes, where draining caused by thaw holes was apparent, to 20-30% above 85^0 North. At higher latitudes a granular, crusty snow of 10-20cm was observed.

There were only a few occasions when concentration dropped to 8/10, and a few when it reached 9+/10. The latter observations were made outbound between 87 and 88^0 North, during a 12 hour period of sustained 30 knot south-easterly winds.

At no time was it necessary for the vessel to resort to high impact speed ramming. On a number of occasions, particularly during the light to moderate pressure noted above, the ship did come to stop under full power, usually against relatively heavy ridging. In these cases it was reversed about 100m and slowly brought back up to speed, sometimes on a different heading. At point of impact speed was usually only a few knots, and the ship continued to accelerate through the "ram". Loosening the vessel in this manner was all that was required to assume normal icebreaking transit.

The North Pole was reached at 0900 August 8, 1990. Following a ceremony and ice properties data collection, the voyage south began at 2130 hours the same day. The inbound track, which had drifted intact to the west a distance of up to 12 n.mi., was followed for the first 12 hours before taking a heading towards the Franz Joseph Islands. The pack ice was cleared at 0200 August 10, and after a tour through these islands the vessel returned directly to Murmansk through the open water of the Barents Sea.

Plate 2-7 Arrival Ceremony on the Ice
North Pole, August 8, 1990

3.0 SHIP PARTICULARS

This section provides an overview of the vessel ROSSIA including principal characteristics, layout, propulsion system machinery, sea performance trials results and special icebreaking features. The information has been compiled from several sources, including personal communications with the ship's officers, inspection tours of the vessel, photography of shipboard drawings and technical specifications, and a review of published literature. Information presented includes technical descriptions, equipment specifications, photography and first hand accounts of operational experience with the various systems and components acquired through interviews with the ship's officers.

3.1 Principal Characteristics and Layout

ROSSIA is a triple screw, 55 000 kW turbo-electric icebreaker with four decks, a forecastle and a five storey superstructure. Gross registered tonnage is 20 664 tonnes, overall length is 150 m, beam is 30 m, and maximum draft is 11 m. (On July 31, 1990, departing Murmansk, the ships draft was measured at 10.8 m forward and 11.5 m aft.) The hull is divided into eight compartments. Principal characteristics are listed in **Table 3.1**.

Figure 3-1 provides a general plan view layout of the vessel, with numbered elements listed in **Table 3.2**. The drawing is taken from Demyanchenko and Livshits (1984). (This paper, published before ROSSIA was commissioned for Arctic service, provides a general description and primary specifications for the ROSSIA. Various novel design features for the ARCTICA series as a whole, as well as changes and refinements incorporated into the ROSSIA, are referred to without details being given. The authors anticipate exceptional icebreaking capability, reliability, safety and structural adequacy for the vessel.)

The hull form is partially illustrated in two elevation sections which can be seen in **Plates 3-1** and **3-2**. These photographs show illustrations which were posted on the navigation bridge bulkhead. **Plate 3-3** is a photograph of a similarly posted drawing, showing front and side elevation sketches. In addition, detail drawings of a total of fourteen plan view sections were photographed on board the vessel, and are available in the main photography log, Appendix C. **Plates 3-4** and **3-5** show photographs of the ROSSIA bow taken at the North Pole.

Very little information could be obtained related to the hull structure. Demyanchenko and Livshits describe the hull as made of high-strength steel with transverse framing, with main and intermediate frames of the same profiles. Bow plating is apparently 45 mm thick.

3.2 Propulsion System

Primary power is provided on the ROSSIA by two nuclear reactors housed side-by-side in separate airtight compartments located midships. Reactor heat is drawn off by a high pressure hot water system (300^0C, 130 kg/cm^2) later used to generate steam. A schematic layout of the ROSSIA's propulsion system us included in **Figure 3-2**.

Table 3.1

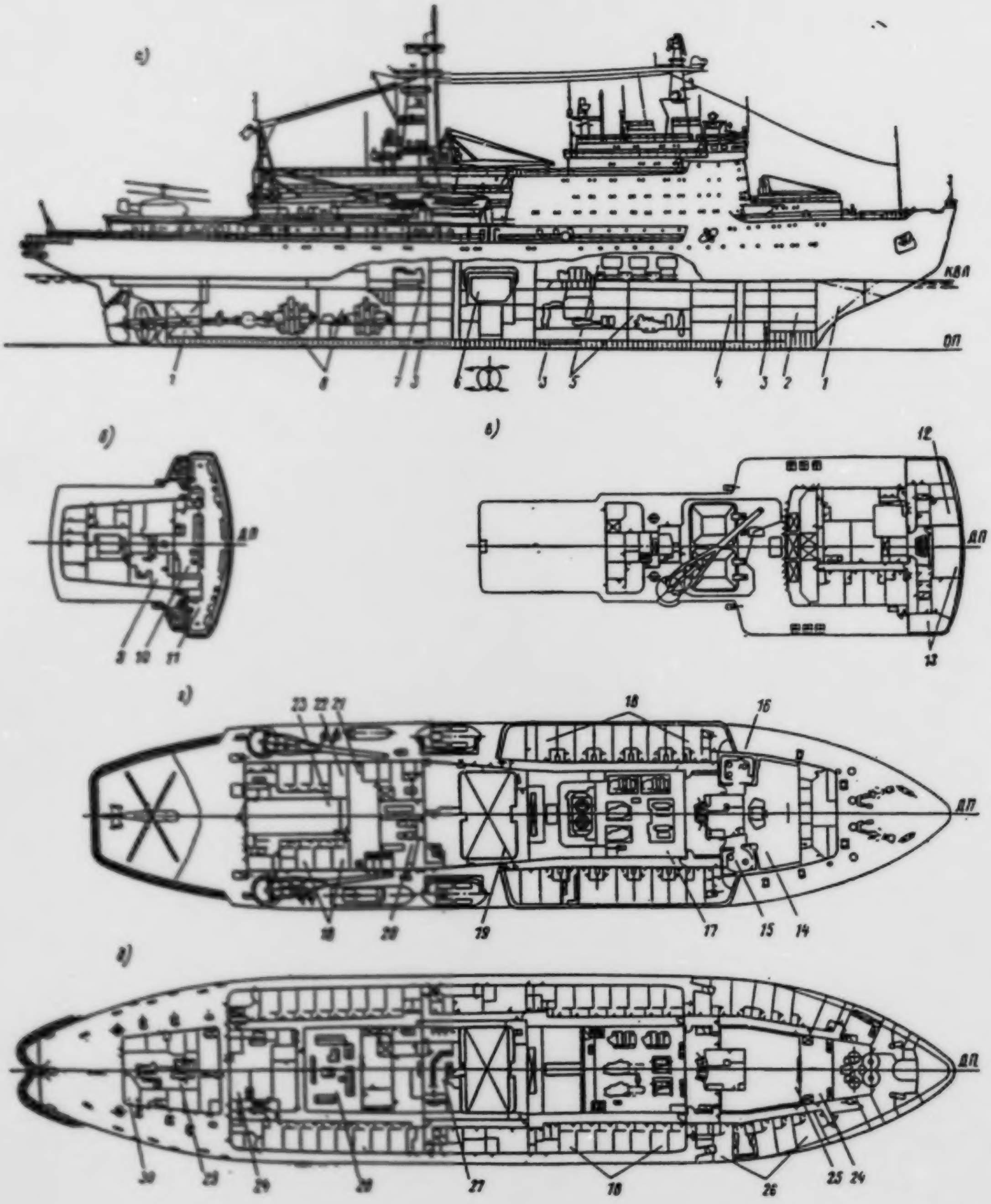
Principal Characteristics of ROSSIA

Length	
overall	150.0 m
between perpendiculars	136.0 m
Beam	
maximum	30.0 m
molded	28.0 m
Height above keel	
upper deck	17.6 m
highest point	53.8 m
Design draft	
maximum	11.0 m
minimum	10.5 m
Displacement, gross registered	20 664 tonnes
Capacity, registered	6 199 tonnes
Deadweight	2 685 tonnes
Propulsion	
maximum power	55 000 kW
maximum bollard thrust	4 700 kN
Call sign	UPIG
Owner	Murmansk Shipping Company, Murmansk U.S.S.R

* * *

Figure 3-1

General Layout of ROSSIA


а)
КВЛ
ОП
1
8
7
3
6
3
5
4
3
2
1
б)
ДП
9
10
11
в)
12
ДП
13
г)
23
22
21
18
16
ДП
18
20
19
17
15
14
д)
ДП
30
29
29
28
27
18
26
25
24

Source: Demyanchenko and Livshits (1984)

Table 3.2

Descriptions for Numbered Elements Appearing in the General Layout of Figure 3-1

1	fore and aft trim tanks
2	trim system pump compartment
3	ice box
4	provisions storage
5	main turbogenerator and auxiliary mechanisms compartment
6	nuclear powered steam generator
7	stern electric power plant
8	propulsion electromotors
9	radio room
10	chart room
11	navigation bridge
12	chief engineer's quarters
13	captain's quarters and meeting room
14	dining room
15	nature room
16	lounge
17	auxiliary boiler and water desalination machinery room
18	officers' cabins
19	instrumentation room
20	emergency diesel generators room
21	physical recreation room
22	laboratory
23	helicopter hanger
24	fore and aft ventilation rooms
25	cafeteria
26	crew cabins
27	hall and stairway
28	main control room
29	towing winch room
30	stern control room

Plate 3-1 Longitudinal Elevation Section
(deck elevations shown: 12.14, 14.54, 16.94, 19.44, 22.04m)

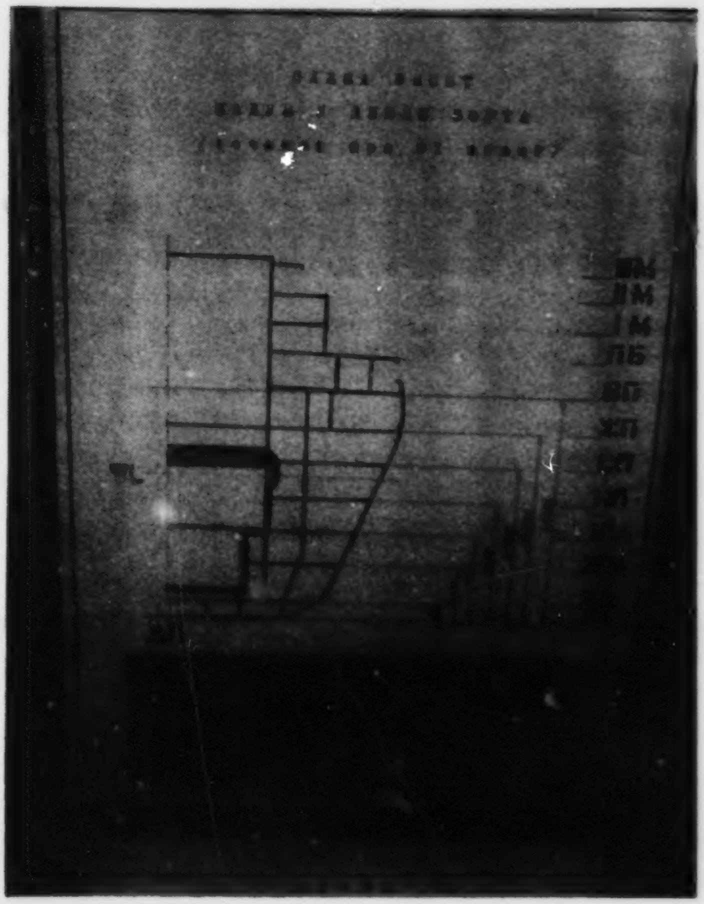


Plate 3-2 Transverse Elevation Section at Midships
(deck elevations shown: 1.5, 4.0, 6.4, 9.6, 12.0, 14.9, 17.6m)

Plate 3-3 Front and Profile Elevation Sketches

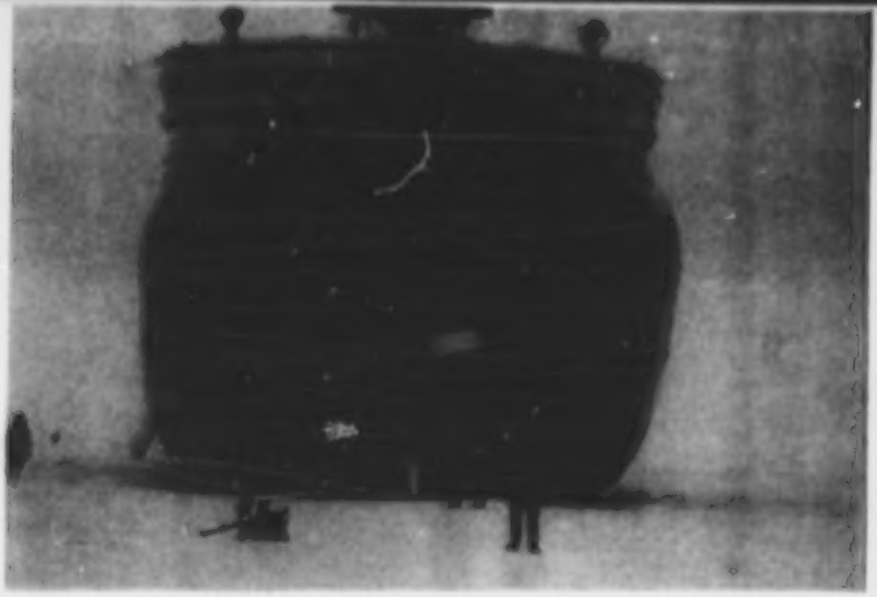


Plate 3-4 Bow of the ROSSIA, Front View
North Pole - August 8, 1990

Plate 3-5

Bow of the ROSSIA, Side View
North Pole - August 8, 1990

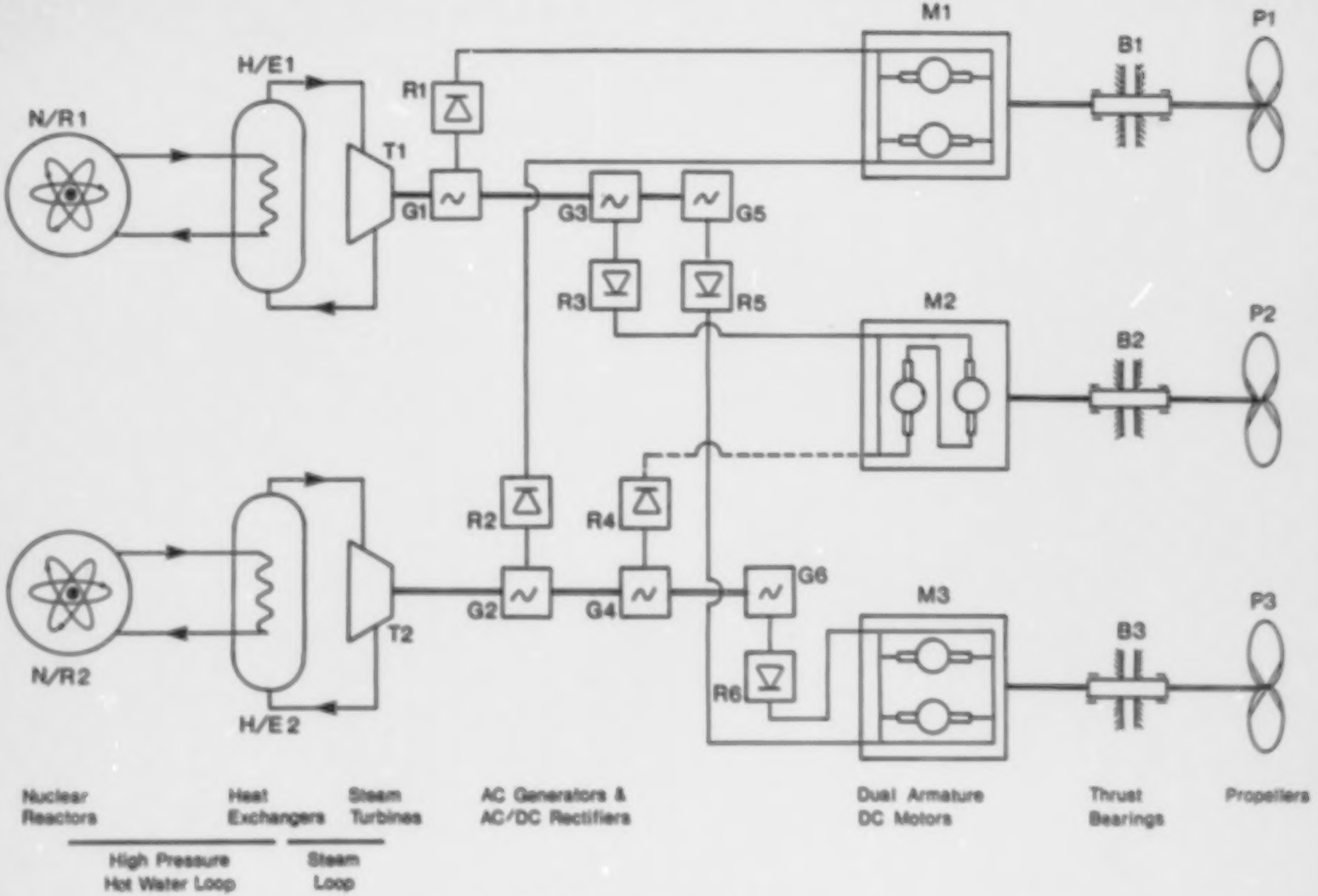

M1
P1
B1
H/E1
R1
N/R1
T1
G1
G3
G5
R3
R5
M2
P2
B2
R2
R4
G2
G4
G6
M3
P3
B3
N/R2
T2
R6
H/E2
Nuclear Reactors
Heat Exchangers
Steam Turbines
AC Generators & AC/DC Rectifiers
Dual Armature DC Motors
Thrust Bearings
Propellers
High Pressure Hot Water Loop
Steam Loop

Figure 3-2 ROSSIA Propulsion System Schematic

The reactors are apparently of the same design and construction as those used successfully for many years on board ARCTICA and SIBIR. Two identical but independent reactor system control panels are manned continuously by separate operators, lowering the risk of human error and enhancing safety. Automated systems are employed to monitor the reactor's fuel core, processes and equipment.

A total of 8 heat exchangers (4 per reactor) convert hot water from the nuclear reactors to steam at 30 kg/cm^2. Maximum steam generation capacity was given as 480 tonnes/hour, about twice the amount required for typical icebreaking operations.

Two steam turbines, one per reactor circuit, convert thermal to mechanical energy. Each turbine develops a maximum power output of 27.5 MW at 3 600 rpm, and is directly coupled to three in-line AC generators. The generators are each rated at 9 000 kW, producing 780 V at 116.7 Hz (6 phase power smooths current pulsation). Each generator feeds directly to one of six solid state AC/DC rectifiers.

The AC generators are paired one from each reactor/turbine circuit, and connected in parallel to three dual-armature variable speed DC motors, one for each propeller drive. The air-cooled motors are rated at 1 000 V, 17 600 kW each. Pairing generators in this manner ensures power will be delivered to each drive in the event that either reactor/turbine circuit should fail. Should any single generator fail, the dual armatures of the DC motors can be series-connected to the single remaining generator in order that the drive in question can be maintained (if at reduced power). This connection is represented for the centre drive in the schematic of Figure 3-2.

Three equal size, variable speed fixed pitch propellers are coupled to the DC motors through three main thrust bearings. During normal operation the port side propeller rotates counter-clockwise while the centre and starboard side propellers rotate in the clockwise direction. The propellers are constructed from a nickel-cobalt alloy. Each one is 5 m in diameter, and weighs 54 tonnes.

This design is essentially the same as that used in earlier ARCTICA series vessels, with the exception of heavier and more easily serviced DC motors for the ROSSIA. The DC drive was originally selected to provide maximum flexibility for icebreaking operations. The newer TAYMYR class of nuclear icebreaker, on the other hand, uses a fully AC electrical system which eliminates certain components related to AC/DC power conversion. However, the AC motors are more complicated than their DC counterparts and have been found to require much higher maintenance. The engineers we spoke with were undecided as to which of the two systems were preferable for application on these highly capable icebreakers.

3.3 Auxiliary Power

A 1 000 kW ship power supply is provided by five 200 kW turbine/generator units also powered by steam from the nuclear generator. A backup 1,000 kW diesel generator is maintained in the "ready to go" condition at all times.

3.4 Special Icebreaking Features

3.4.1 Air Bubbler System

The ship is equipped with an air bubbler system to lubricate the hull and combat ice build-up at the waterline during icebreaking operations. This system has been found very satisfactory and is employed extensively during icebreaking. We were advised that operations often depend on the availability of the bubblers, and that with them there is virtually no need to use the trim and roll system. (The bubblers were used continuously on the North Pole voyage while operating in ice.)

As much as 10% of total ship power (30 tonnes/hour of steam) is tapped to operate the bubblers. Air is delivered at up to 30 kg/sec through 36 jets. There are 16 jets on each side, beginning behind the bow at frame # 19 and ending midships at frame # 90, and 4 jets at the stern.

The side jets are all 200 mm in diameter and are located 0.5 m above the keel line. Each one projects 350 mm beyond the shell plating (no reason was given for this projection). The stern jets vary between 150 and 200 mm diameter (the smaller jets being located higher up), and are flush with the shell plating. The only disadvantage acknowledged with the system was the noise and vibration caused by the 1 200 rpm compressor turbines.

3.4.2 Trim and Roll System

A ballast transfer system designed to quickly alter ship trim and roll was also provided to assist operations in ice. However, there has apparently never been a need to use the system for this purpose.

The system comprises four separate tanks and pumps, two fore and two aft. In open water, the 1 000 and 3 000 tonnes/hour pumps are able to affect a rolling period of 30 seconds. The engineers had no experience with its use in ice. The system has only been used operationally to adjust trim for the purposes of stem to stern towing, and it was not known what the cycle time was to effect maximum trim adjustment. Although controls for this system are provided on the bridge, adjustments are usually made by the engineers.

3.4.3 Shell Plate Heating System

A third system designed to aid icebreaking operations involved the installation of electrical heat tracing elements against the inside shell plate along the ice belt, beneath the insulation. The idea was that ice build-up along the hull could be prevented by heating the shell plate. However, for undetermined reasons, the system has never worked and is now considered permanently unserviceable.

3.4.4 Ice Piece Deflectors

Around the period in which ROSSIA was constructed, modifications were made to ARCTICA which involved the addition of large bulging appendages to the hull, just aft of the bow and below the water line (seen in Plate 3-3). These projections were intended to deflect broken ice pieces underneath the surrounding ice, away from the propellers and out of the ship's track. In the case of the ARCTICA, these appendages were separate attachments welded onto the existing hull. It was decided that ROSSIA should have similar ice deflectors, and these features were incorporated into her construction.

The deflectors were entirely unsuccessful. They impacted negatively on ship performance, and were soon severely damaged during normal icebreaking operations. They were therefore removed from both vessels. In the case of ROSSIA, because they had been incorporated into the hull construction, it was a difficult and costly refit. **Plate 3-6** shows a photograph of the damaged starboard deflector.

3.5 Performance and Manoeuvring in Open Water

In calm seas, with both nuclear reactors operating at 55% of full power and bridge controls at full ahead, ROSSIA maintained a top cruising speed of 19 knots.

Manoeuvring performance documented during sea trials of ROSSIA are illustrated in **Plate 3-7**. This photograph shows a document which was posted on the navigation bridge, entitled "Table of Manoeuvring Elements".

Across the top of the document are scale drawings showing open water turning circles. Axis are graduated in cables (tenths of a nautical mile). Trials were conducted at both 18 and 10 knots. At 18 knots two turns, with rudder angles at 35^0 and 15^0, were made to both port and starboard (top left hand drawing). At 10 knots, port and starboard turns were made at a 35^0 rudder angle only (top centre/right drawing). The results of these trials are tabulated in the bottom left under the title of "Circling". The left and right hand portions of this table provide results for the 18 and 10 knot trials, respectively. For both speeds the change in heading in degrees is listed down the centre, with the times to achieve that change shown to either side (corresponding to port and starboard trials) for both the 35^0 and 15^0 rudder angles. Elapsed time is given in minutes and seconds.

Turns made with a 35^0 rudder angle varied from 3.4 to 3.9 cables across the circle, depending on initial speed, turn direction and the measurement axis. Turns made with a 15^0 rudder angle similarly varied between 5.2 and 6.6 cables across the circle.

The line graph in the centre of the photograph shows the relationship between ship speed in knots (y-axis) and propeller speed in rpm (x-axis). Two different curves are plotted for the side propellers (upper curve) and the centre propeller (lower curve). The curves are approximately linear to 16 knots (125 rpm), after which point the increase in speed with rpm begins to fall off.

Plate 3-6 Damaged Starboard Ice Piece Deflector

Plate 3-7 Table of Open Water Manoeuvring Data

The table in the bottom centre of the photograph is titled "Increase of Draft" and lists the resultant increase in drafts from a starting measure of 10.65 m corresponding to degrees of list (top two rows) and to "deflection on circling" for speeds ranging from 4 to 18 knots at two different water depths, 14 m and 18 m (bottom three rows). For example, with a list of 11 degrees, the vessels draft is increased by 2.6 m; at a speed of 12 knots, turning hard over in 18 m of water depth, the vessels draft is increased by 0.9 m.

Against the right hand side of the photograph is a bar graph showing crash stop test results. The vertical axis gives stopping distance in cables, and the time to stop is recorded at the top of the bar. The four cases presented are, from left to right: 1) initial speed 18 knots, from full ahead to full reverse, stopping distance is 2.6 cables in 01:45 (minutes:seconds); 2) initial speed 12 knots, from full reverse to full ahead, stopping distance is 1.1 cables in 01:55; 3) initial speed 12 knots, from full reverse to propellers stopped, stopping distance is 12.0 cables in 05:00; and 4) initial speed 18 knots, from full ahead to propellers stopped, stopping distance is 16.0 cables in 17:33.

In the bottom right hand corner is a figure showing the appropriate manoeuvre to turn the vessel around in case of a man overboard alarm.

4.0 ICE INFORMATION AND NAVIGATION

This section describes the various ice information and navigation tools which were available to support the North Pole voyage, including information sources, product types and methods of communicating information to the ship.

4.1 Soviet Ice Information Services

The Arctic and Antarctic Research Institute (AARI), with headquarters in Leningrad, is the principal agency in the USSR dealing with climate and meteorology (p.c. Karpekin, 1990). It is operated by the State Committee for Hydrometeorology, Moscow. The AARI supports diverse research and operational support activities. Of particular interest to Arctic marine navigation are the following departments:

- remote sensing,
- meteorology,
- oceanography,
- ocean/ice atmosphere interactions,
- long range meteorological forecasts,
- long range ice forecasts,
- physical and mechanical properties of ice, and
- ship performance in ice.

The department of long range ice forecasts provides information to support shipping along the Northern Sea Route (NSR), the majority of which is organized well ahead of time into icebreaker escorted convoys. Both current and prognostic charts covering the entire northern coast of the USSR are updated every ten days. Longer range forecasts (1 month, 6 month and 1 year) are also issued.

The following brief overview of the AARI ice reconnaissance, analysis and forecasting operations at Leningrad is based on Falkingham (1990), an unpublished record of information acquired during a technical exchange visit to the AARI in January/February 1990.

Ice analysis and forecasts are based on low (4 km) resolution NOAA, METEOR and active microwave radar satellite imagery, complimented by an aerial ice reconnaissance service. Many Canadian marine operators are familiar with the NOAA and METEOR visual and infrared imagery products, however the availability of an all-weather capable radar satellite will be of particular interest. Satellite data are picked up at Leningrad using an Automatic Picture Transmission (APT) receiver and a manually controlled tracking antenna. The SLAR satellite senses a 380 km wide swath at 4 km resolution. Unfortunately, the satellite has no recording capability, and therefore data can only be received on line of sight.

Two four-engine turboprop aircraft (Ilyushin-18's) are employed for ice reconnaissance. The primary sensor in each aircraft is a SLAR, designed for operation at an altitude of 6 000 m. For this reason, visual observations are not normally conducted. The only other sensors available on the aircraft are aerial photography cameras. Each SLAR provides dual side, 45 km swath imagery. Resolution is 40 m in the range direction and 30 m in azimuth. Hardcopy imagery (there is no real-time display) can be produced at either 1:500 000 or 1:100 000 scale.

Strategic ice reconnaissance missions are typically conducted monthly, over a single 10 day period. There are 10 standard flight tracks, which combined provide coverage from 40°E eastward to the Canadian Arctic archipelago, and north from the coastline to the North Pole. Following each flight, ice conditions are relayed by telex to AARI in the form of coded text.

Falkingham reports that according to the AARI, tactical support is available to ships in the form of line-of-sight airborne SLAR imagery downlinks to ships (the aircraft have no data recording capability), as well as post-mission ice analysis chart transmissions to ships via marine radio facsimile. As discussed in the following sub-section, no such facilities were available on board ROSSIA.

4.2 Ice Information Received On Board ROSSIA

Under normal operating conditions, the only ice information products routinely available to the navigator (besides close tactical visual and marine radar) are visual reconnaissance charts produced by an ice observer using the ship's own helicopter.

Another source of data (used only rarely, we were told) is hardcopy SLAR imagery dropped physically to the ship from the AARI ice reconnaissance aircraft. This may be what was referred to as "downlinking" in the previous section. **Plate 4-1** shows a mosaic of SLAR imagery which was prepared on board the ROSSIA during the 1989 season. The area covered lies off the east coast of Severnaya Zemlya. The quality of the imagery appears similar to that provided by our own ice reconnaissance service.

Equipment for receiving marine facsimile transmissions was apparently available aboard ROSSIA. However, the radio officers we spoke with acknowledged that the service was available "in principle only". The equipment was not thought to be functional, and in any event none of the officers were familiar with its operation.

There was no APT receiver aboard ROSSIA for the purposes of receiving satellite data directly.

Plate 4-1 SLAR Imagery Mosaic Prepared On Board ROSSIA Showing the East Coast of Severnaya Zemlyain Spring 1989

4.2.1 Helicopter Reconnaissance

Helicopter support for this voyage included two MI-2 twin turbine, single rotor aircraft, each of which could carry up to six passengers (see **Plate 4-2**). Normally, the ROSSIA carries one MK-3 single turbine, twin rotor (counter-rotating) aircraft.

Two ice reconnaissance crews accompanied the vessel. Each crew comprised one pilot and one ice observer, known as the hydrologist. Aircraft support is provided by Aeroflot, while the hydrologist is considered a member of the ship's crew.

The Soviets rely much more heavily on helicopter reconnaissance than do Canadian Coast Guard icebreakers. Reconnaissance flights were conducted several times daily even while transiting light ice conditions (decayed first-year ice). Below 80^0 N, the helicopter would be away from the vessel for up to several hours at a time, and on return to the vessel the hydrologist would prepare observed charts covering long sections of the planned route. A partial example of such a chart is shown in **Plate 4-3**. This chart, prepared at a scale of 1:500 000, shows a 3-4 n.mi. wide observation corridor for conditions east and north of Komsomol Island (Severnaya Zemlya). It was produced on August 2, while the ROSSIA was located in the southern Kara Sea. Soviet ice chart symbology is different from the internationally recognized egg code used in Canada. A guide to these symbols is included in **Table 4.1**.

Once into the multi-year pack ice, the helicopter was flown on a virtually continuous basis. It returned to the ship only to refuel and change crew, or when visibility was reduced below 1 or 2 miles. Even in marginal visibility, the VFR helicopter was flown extensively. The two flight crews alternated missions, searching out the easiest ice conditions up to 20 or 30 km ahead of the vessel. Radio communication with the ship was maintained, and once the preferred path was determined the helicopter would hover as appropriate to guide the vessel. At such times the wheelsman would steer on the helicopter, taking occasional orders from the commanding officer.

This technique is apparently common practice in the USSR, and was seen to be very effective. Vast and giant floes were generally avoided, and the vessel followed a path of broken leads and smaller floes for most of the ice transit. It appeared however, that the emphasis on effective support may have been made at the expense of safety. Several times during the voyage, the air crews appeared fatigued following long missions. Although there was no obvious reason to doubt that maintenance of the helicopters was adequate, the aircraft were very dirty compared to those used in the Canadian Arctic, and personal safety measures for passengers were almost non-existent.

4.2.2 Dedicated Support from AARI

A dedicated airborne reconnaissance flight was undertaken by AARI on August 2, 1990 to support the North Pole voyage. The resultant 1:1 million scale analysis chart is reproduced in the photographic mosaic of **Plates 4-4** and **4-5**.

Plate 4-2 One of Two MI-2 Twin Turbine Helicopters Carried Aboard ROSSIA for Ice Reconnaissance Purposes

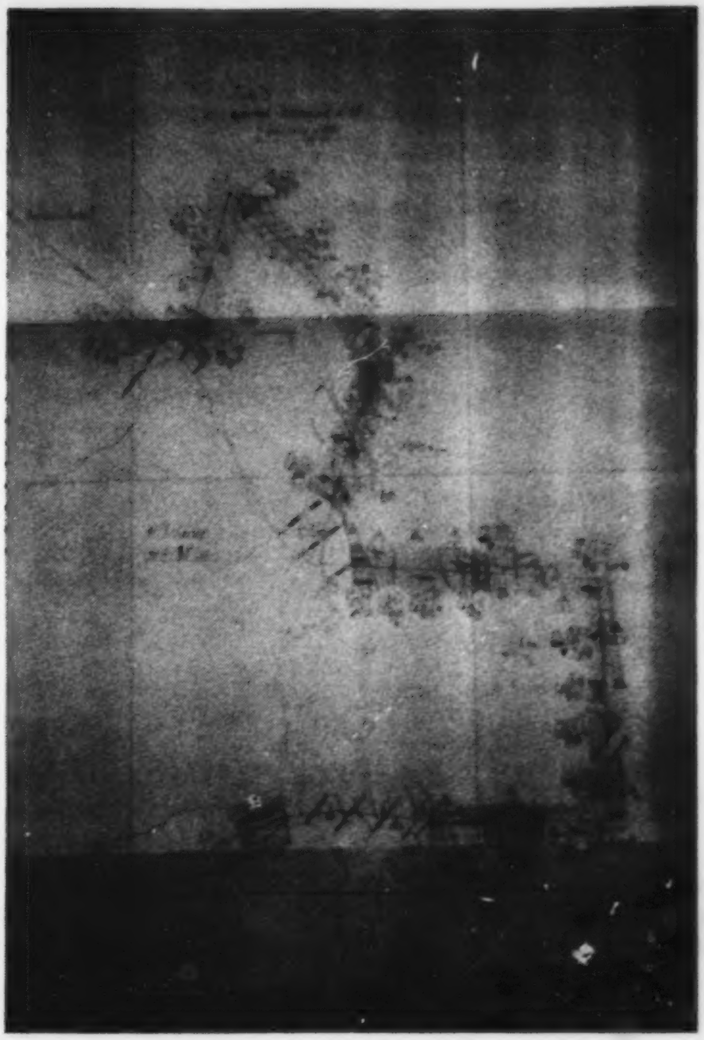
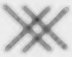
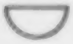
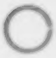
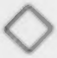
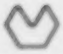
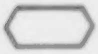
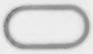
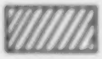


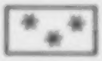
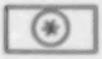
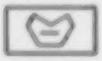
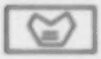
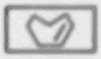
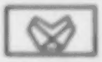
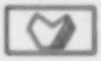
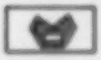
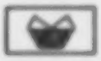
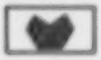
Plate 4-3 Helicopter Reconnaissance Chart Showing Conditions East and North of Komsomol Island (Severnaya Zemlya) August 2, 1990

Table 4.1 Soviet ice chart symbology.

Floe size:

	Brash ice	≤2 m
	Ice cake	≤20 m
	Small floe	20 - 100 m
	Medium floe	100 - 500 m
	Big floe	500 m - 2 km
	Vast floe	2 - 10 km
	Giant floe	>10 km
	Fast ice	

Ice type (symbols may be accompanied by partial concentration):

	Frazil	
	New	<10 cm
	Grey	10 - 15 cm
	Grey - white	15 - 30 cm
	Thin first - year	30 - 70 cm
	Medium first - year	70 - 120 cm
	Thick first - year	>120 cm
	Old	up to 3 m and more
	Second - year	up to 2.5 m and more
	Multi - year	≥ 3 m

Topography:

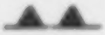
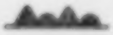
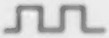
	Ridging
	Rubble
	Rafting

Plate 4-4 AARI Airborne Ice Reconnaissance Chart
77-83° N. Latitude - August 2, 1990
With Ship Route from 1100 hrs August 4 to 1700 hrs August 5

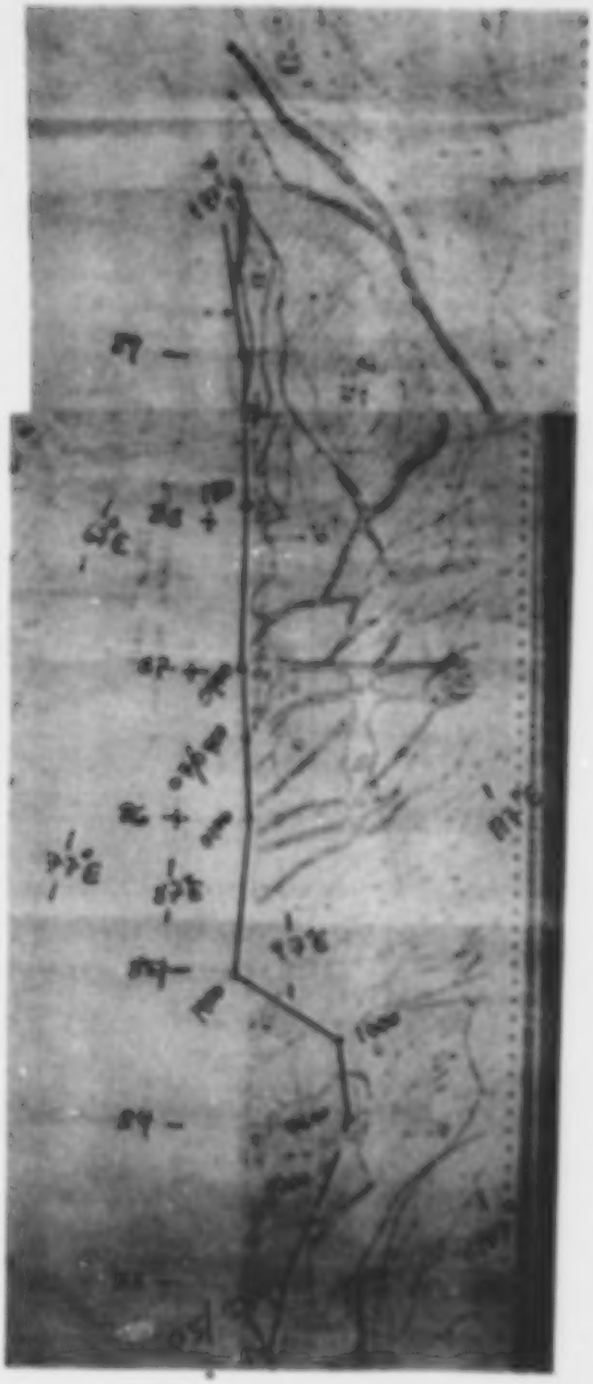


Plate 4-5 AARI Airborne Ice Reconnaissance Chart
83-90° N. Latitude - August 2, 1990
With Ship Route from 2300 hrs August 5 to arrival at the North Pole on August 8

Data from this mission were combined with satellite imagery analysis to produce a special composite ice chart showing conditions which ROSSIA could expect en route to the pole. This chart is reproduced in the photographic mosaic of **Plate 4-6**. We were advised that both satellite and visual inputs were restricted due to low cloud, and that for this reason the accuracy of the chart was limited.

The reconnaissance chart in Plates 4-4 and 4-5 shows ice concentrations, topography and major leads within a 100 n.mi. wide corridor. The corridor passed along the east coast of Severnaya Zemla in a north-westerly direction, before turning north to the North Pole. As can be seen from the track plotted on these photographs, the route followed by ROSSIA north of 85° N lay just west of the reconnaissance corridor. It is worth noting however, that the information was already 4 days old by the time the ship crossed 85° N, and in the dynamic Arctic ocean gyre ice conditions could be expected to have changed, perhaps very significantly, from those shown on the chart.

This chart was relayed from the AARI, apparently by radio facsimile, to various regional centres including a station at Dixon, located on the north coast of the southern Kara Sea (approx. 73°40'N, 81°E). The chart was brought to the ROSSIA from Dixon by Masutkin (MSC) and Makarov (AARI), when they joined the vessel by helicopter on August 3, 1990. Hard copy reproductions of what appeared to be METEOR satellite imagery also arrived with the helicopter from Dixon. Ice conditions in these images were almost completely obscured by cloud cover.

4.3 Vessel Navigation

4.3.1 Bridge Layout and Navigation Equipment

The ROSSIA bridge layout could be termed conventional. The wheel was located forward and centre, immediately in front of the bridge windows. A main control panel was located to the right of the wheel, beside which was a small chart table used primarily by the ice observers. This area was graciously made available to us for this study.

To the left of the wheel was a Norwegian built DATABRIDGE-7 ARPA DISPLAY marine radar, manufactured by Norcontrol Simulation AS (model DB-7 MK II). The chart table was located further to the left. Ship's position was plotted on the chart continuously by an X-Y plotter. Above the chart table were mounted a Soviet made depth sounder, and a FURUNO satellite navigator (model FSN-70). Beside the chart table was mounted the primary navigation tool, a Danish built SHIPMATE global positioning system receiver (model RS 5310).

One auxiliary control console and one older looking, Soviet built marine radar were located on each bridge wing. The chart room was located immediately aft of the conning area, as shown earlier in Figure 3-1.

Plate 4-6

AARI Ice Analysis/Forecast Chart
Delivered to ROSSIA August 3, 1990

Plate 4-7 shows a view of the bridge deck. Photography was not permitted at the port side of the bridge, near the chart table. (The Soviets have long kept accurate maps and charts secret). **Plate 4-8** shows the starboard auxiliary control panel, with main control levers for each of the three propellers.

4.3.2 Navigation Practices

The navigation bridge watch structure comprised two officers and two Able Seamen (ABs). The Captain and the Chief Mate shared command, rotating 6 hour shifts, while the First Officer was responsible for deck activities and passengers. Three junior officers and the ABs kept standard four hour watches. One AB was on the wheel at all times, while the other kept watch or did odd jobs on the bridge.

As described above, strategic information products available on board the vessel were of limited practical use, and the primary tactical navigation aid employed by the ship's navigators was helicopter reconnaissance.

Close tactical navigation depended on visual reconnaissance from the bridge. The three marine radars installed on the vessel bridge which were seldom turned on, and very rarely used for navigation except near the coastline. The ARPA and one of the older radars were turned on for only 8% and 6% of the total time in ice, respectively.

Plate 4-7 Navigation Bridge Deck on the ROSSIA
August 3, 1990

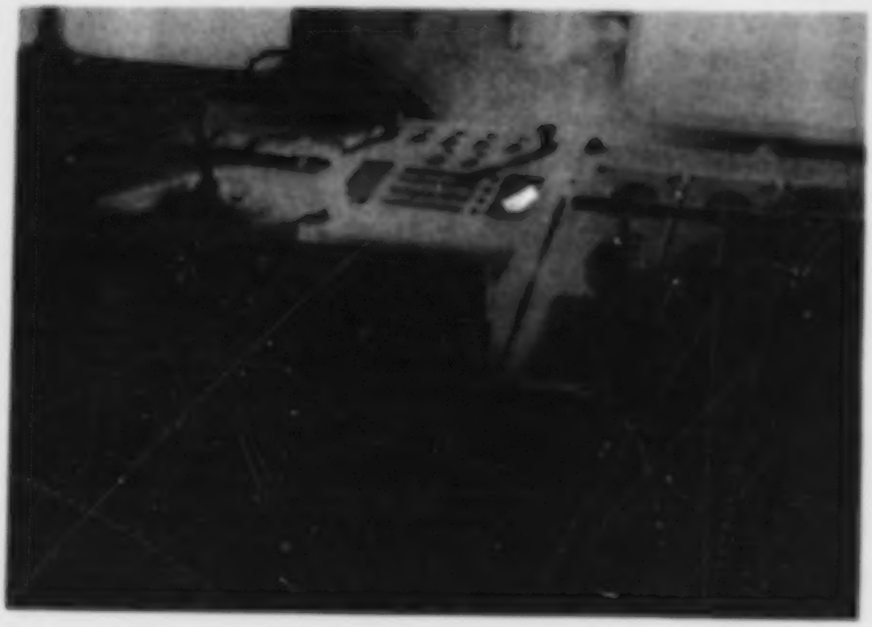


Plate 4-8 ROSSIA's Starboard Wing Auxiliary Control Panel

5.0 ICE CONDITIONS AND VESSEL PERFORMANCE

The majority of data currently available which describe ice conditions in the Arctic Ocean, do so from a regional perspective. There are different reasons for this. In the case of satellite sensors, spatial resolution has typically been relatively low, in the order of kilometres. Where higher resolution data (in the order of metres or tens of metres) are available, such as airborne laser profilometer or submarine upward-looking sonar, the data are usually presented in the form of statistical descriptions of relatively long, straight transect lines which reflect regional variability in ice conditions.

Icebreaking ships however, normally operate with a view to exploiting the lightest possible ice conditions. Their perspective is therefore local, and furthermore skewed towards favourable navigation conditions. In the study of icebreaker operations, from navigation systems to ice loads, it is therefore tactical, route-specific data which are most needed and least available. For this reason, the records of ice and environmental conditions encountered by ROSSIA during the North Pole voyage are a unique and important data set.

This section begins with a brief overview of regional total ice concentrations, based on passive microwave satellite data. This is followed by a description of the shipboard observation data set. In the third sub-section trafficability data, which describe ice conditions and their relationship to vessel performance, are summarized for route segments characterized by relatively constant conditions. The section closes with ice physical properties data collected at the North Pole.

5.1 Regional Ice Conditions

Satellite data describing regional total ice concentrations were collected for the area and period of the ROSSIA voyage by the Institute for Space and Terrestrial Science (ISTS), York University. The sensor employed was the Special Sensor Microwave/Imager (SSM/I) carried aboard a U.S. Defence Meteorological Satellite Program (DMSP) spacecraft. The SSM/I is a seven channel, four frequency passive microwave radiometric system which measures atmospheric, ocean and terrain microwave brightness temperatures (Hollinger *et. al.*, 1989).

Ice data were generated on a daily basis by ISTS using the Canadian AES/York algorithm, which employs the 19.3 and 37.0 GHz frequency data to analyze and plot sea ice parameters including total ice concentration, old ice fraction and ice edge location (Ramseier *et. al.*, 1990). Unfortunately, the ROSSIA carried no equipment capable of receiving graphic products and we were therefore unable to make the data available in the field to support navigation. Characteristics of the SSM/I are summarized in **Table 5.1**.

Table 5.1

Characteristics of the SSM/I

Spacecraft: US DMSP Block 5D-2 F-8
Orbit: circular sun-synchronous near-polar
Altitude: 833 km
Inclination: 98.8^0
Orbit Period: 102.0 min
Swath Width: 1,400. km
Resolution: 25 km

Figures 5-1 and **5-2** illustrate regional total ice concentration for August 3 and 10, 1990 which correspond approximately to the dates on which ROSSIA entered and exited the polar pack ice (August 2 and August 11, respectively). Satellite footprints are coloured to represent six total ice concentration levels as described in the figure's legend. It is important to note that footprints bordering coastlines may contain land contamination, resulting in higher concentrations of ice being reported than were actually present in that location.

The two figures clearly show the range and variability of regional ice conditions which existed during the study period. The main pack ice edge was generally stable, extending from the northern coast of Svalbard to the Franz-Joseph archipelago, then south-eastward to the north-east coast of Novaya Zemlya Island and down to the Siberian mainland. South of 80^0 North latitude, in the Kara and western Laptev Seas between 70^0 and 120^0 east longitude, ice conditions were seen to lessen over the seven day interval. The maximum extent of ice in the Kara Sea retreated northward by as much as 120 n.mi. (at 75^0 E.) and a large area of 9+ to 10 tenths total ice concentration which lay midway between Novaya Zemlya and Severnaya Islands, is seen to have reduced in size from about 150 n.mi. to only about 30 n.mi. across, with a corresponding reduction in total ice concentration throughout the region.

The vast area of 9+ to 10 tenths which covered the far northern regions on August 3, is seen however to have extended southward about 90 n.mi. between 0^0 and 40^0 E. (the Svalbard area) during the same period. As might be expected given that temperatures were not sufficiently cold to result in significant new ice growth, the extension of this boundary does coincide with the appearance of several resolution cells indicating less than 9+ to 10 tenths ice north of 85^0 N., where none had previously been seen.

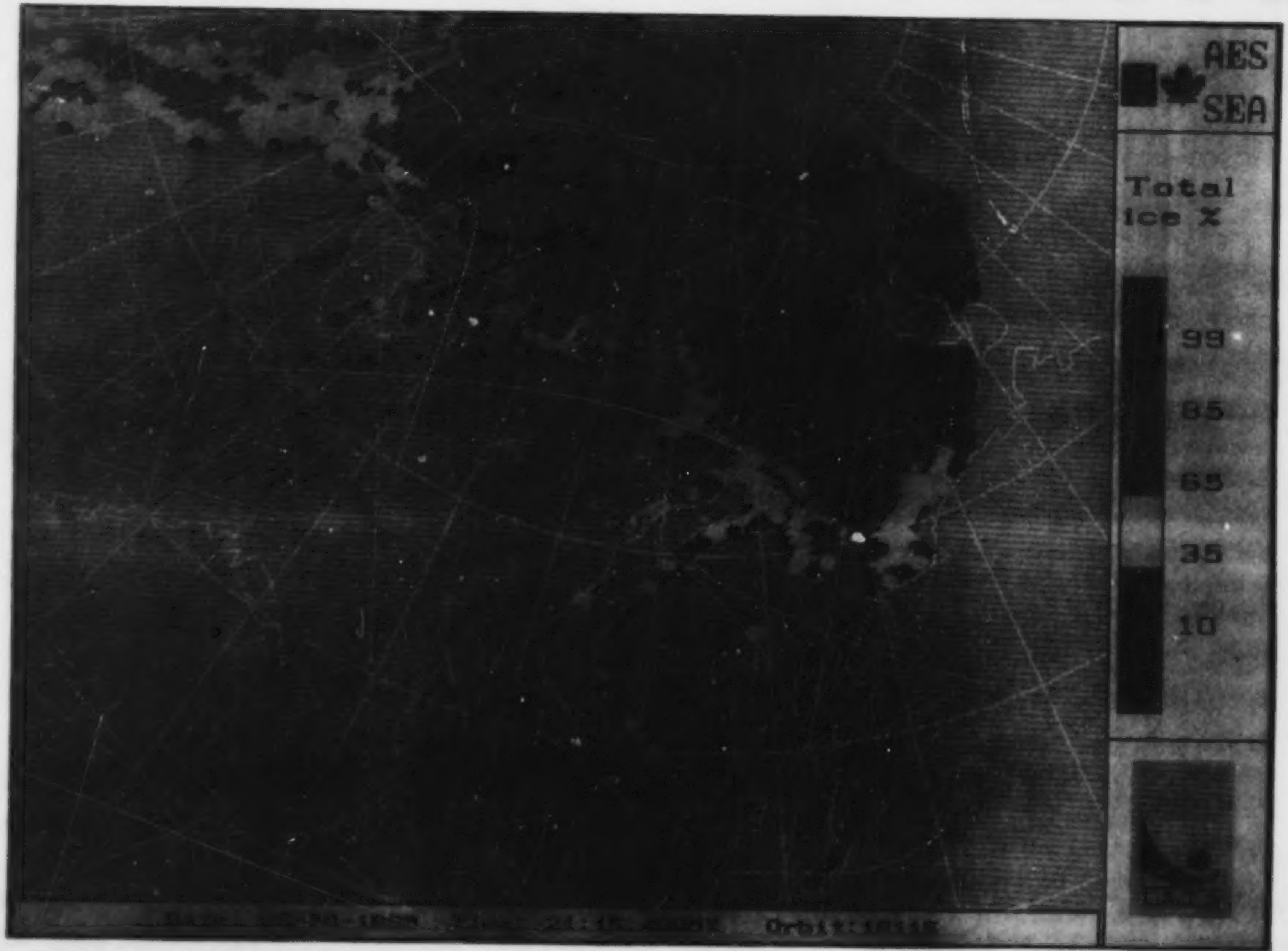

AES
SEA
Total
Ice %
99
85
65
35
10

Figure 5-1 Regional Total Ice Concentration from SSM/I Satellite Data, August 3, 1990

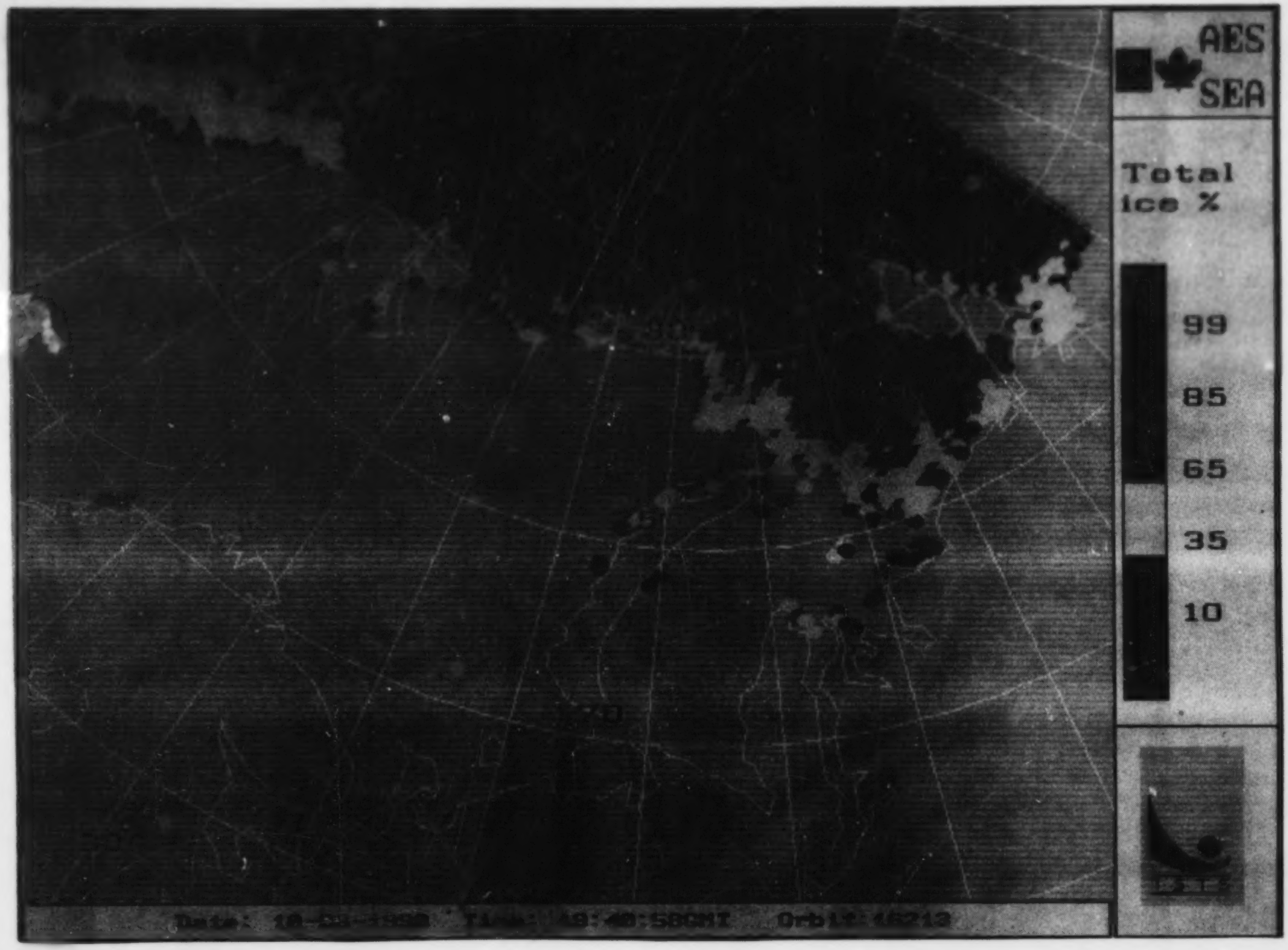

AES
SEA
Total
Ice %
99
85
65
35
10

Figure 5-2 Regional Total Ice Concentration from SSM/I Satellite Data, August 10, 1990

The SSM/I data are generally consistent with visual observations made from the ROSSIA. Ice edge locations correspond well with those observed in the field, within the limitations of the sensor resolution. Also, pack ice conditions north of 80^0 N were significantly heavier during the northbound transit (very close pack ice and frequent light to moderate pressure) compared to the southbound transit (close pack ice with greater numbers and sizes of leads).

The main difference between the satellite data and the shipboard observations was that SSM/I reported a vast region of 99% or greater total ice concentration capping the northern hemisphere, while shipboard observations were consistently in the 9 to 9+ tenths (90-99%) range. As discussed earlier, the cause of this discrepancy can very likely be attributed to the success of tactical navigation efforts in exploiting locally favourable ice conditions, i.e., following leads around the perimeters of vast and giant multi-year floes.

5.2 Shipboard Observations

Within the pack ice, ROSSIA was supported by virtually round-the-clock helicopter reconnaissance, which effectively helped the ship to round the majority of vast and giant multi-year ice floes, following leads and breaking through smaller floe sizes. Hourly records of predominant ice conditions based on observations made from the vessel bridge are generally valid, subject to visibility and ice topography, for a corridor about 6 n.mi. wide along the vessel's path. As such, ice concentrations and floe sizes will often be less than a regional perspective would provide.

Shipboard observations are tabulated and included as appendices to this report. Appendix A provides a listing of data field entry criteria, coding and definitions, as described earlier in the Method of Approach. **Appendix B** contains a listing of the data base in three tables, followed by the supplementary reference diary. Each table lists data records by date, time, event number and event type (hourly or special event). **Table B.1** presents general transit particulars drawing on both hourly and event based records. The table includes: route particulars (date, time, position, course and speed); hourly meteorological observations; marine radar utilization; and cross-references to the 35 mm photography log.

Table B.2 summarizes predominant ice conditions including: total and partial ice concentrations of various ice types; value ranges for both predominant floe sizes and estimated ice thicknesses, for both first-year and old ice; and the quantities of melt ponds, thaw holes and ridging/rubble expressed as estimated percentages of total ice surface. These data represent average conditions for the one hour period preceeding the entry.

Table B.3 lists vessel performance data, including: course and distance made good computed from hourly position records; icebreaking operation mode, expressed as estimated percentages of time spent in each category over the preceding hour; and on-hour records of ship speed, total nuclear reactor power, and for each of the three propellers, power level setting and propeller speed. In addition, corresponding to the on-hour performance data are ice thickness measurements taken from scaled 35 mm and VHS video recordings.

The reference diary in **Table B.4** is cross-referenced to each of the three tables which make up the observation log. It contains a chronological listing of brief narrative descriptions for notable events.

5.3 Vessel Trafficability

In presenting a review of shipboard observations, we have chosen to summarize data for individual, consecutive route segments characterized by relatively constant operations. In this way ice conditions and vessel performance can be presented independently but side-by-side, in terms relevant to icebreaker operations. The summaries describe the distribution of local ice conditions along the cruise route, while at the same time allowing the evaluation of related overall or macro-scale vessel performance.

"Trafficability" is term normally used to describe the relationship between ice and environmental conditions, performance and structural safety, for icebreaking marine vessels. Although no data were collected related to structural loads, we have chosen to use the term trafficability in the title of this section because the presentation includes both ice and environmental conditions, and related vessel performance data.

The sub-section begins by describing our approach to the selection of route segment data sets. This is followed by a description of the data analysis procedure, after which the trafficability summaries are presented and discussed.

5.3.1 Selection of Route Segment Data Sets

Our approach to selecting route segments was to review data with the aim of defining secondary sub-sets, which would form the basis of data analysis and presentation of findings. Each sub-set was to be representative of a particular ice regime, or segment of transit characterized by consistent environmental conditions and vessel operating parameters. Generally, the main criteria employed in the selection of data sub-sets included:

i) Relatively constant ice conditions (ie. ice type and concentration, level ice component thickness, pressure, severity of ridging and rubble, etc.).

ii) Relatively constant vessel operating parameters (i.e., engine power level, ship handling, etc.).

iii) Consideration of external influences (ie. manoeuvring, convoy operations, interruptions attributed to mechanical difficulties, etc.).

The data base was searched in an iterative fashion, with data sub-sets gradually narrowed and focused in respect of the above considerations. In all, a total of fourteen appropriate route segments were identified. These segments are listed in **Table 5.2** and illustrated on the route map included as **Figure 5-3**.

Table 5.2
Route Segments used in Trafficability Analysis

Segment No.	Position (dd.mm N, ddd.mm E) Start	End	Date/Time (August 2-11, 1990) Start	End	Total Segment Distance (n.mi.)	Time (hours)
A	76.33, 69.05	76.41, 70.55	02/0501	02/0700	28.	2.
B	76.41, 70.55	75.50, 89.46	02/0701	03/1500	280.	32.
C	75.55, 90.34	80.11, 99.58	03/1601	05/0400	310.	36.
D	81.26, 95.37	82.51, 96.18	05/1401	05/2200	100.	8.
E	82.51, 96.18	84.14, 100.55	05/2201	06/0800	87.	10.
F	84.14, 100.55	85.27, 92.21	06/0801	06/2200	90.	14.
G	85.39, 92.39	88.10, 95.13	06/2301	07/1900	155.	20
H	88.10, 95.13	89.46, 102.24	07/1901	08/0700	92.	12.
I	89.50, 112.28	88.10, 93.43	09/0001	09/1100	120.	11.
J	88.10, 93.43	86.45, 73.51	09/1101	09/2200	100.	11.
K	86.45, 73.51	83.52, 65.50	09/2201	10/1400	167.	16.
L	83.52, 65.50	82.34, 65.58	10/1401	10/2000	88.	6.
M	82.34, 65.58	82.07, 65.29	10/2001	10/2200	22.	2.
N	82.07, 65.29	81.11, 65.49	10/2201	11/0200	60.	4.

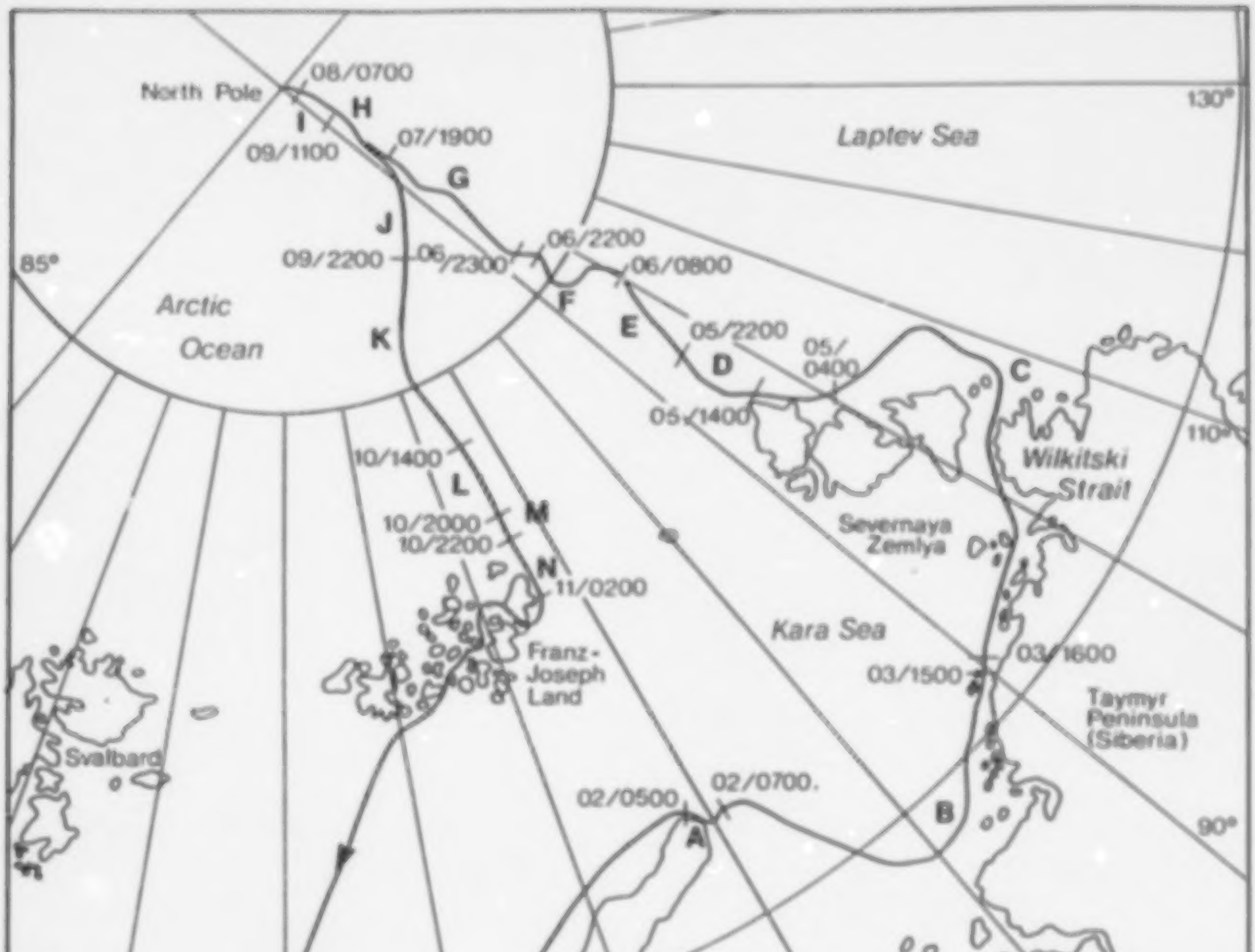

North Pole
08/0700
H
I
09/1100
07/1900
G
Laptev Sea
130°
J
09/2200
06/2300
06/2200
06/0800
85°
Arctic
Ocean
F
E
K
05/2200
05/
0400
D
C
05/1400
110°
Wilkitski
Strait
10/1400
L
M
10/2000
10/2200
N
11/0200
Severnaya
Zemlya
Kara Sea
Franz-
Joseph
Land
03/1600
03/1500
Taymyr
Peninsula
(Siberia)
Svalbard
02/0500
02/0700.
B
90°
A
75°
Novaya
Zemlya
Barents
Sea
Murmansk
Arctic Circle
30°
50°
65°
70°

Figure 5-3 Route map showing trafficability analysis route segments A to N; end points marked with date/time. (August 2-11, 1990)

5.3.2 Data Analysis Procedures

The next step was to undertake a detailed analysis of each data sub-set, from which summary descriptions of vessel trafficability along individual route segments were compiled. Average ice conditions and vessel operating particulars were computed, and the overall or macro-scale performance of ROSSIA through individual ice regimes was evaluated and summarized.

These results are included in **Appendix E, Tables E.1** to **E.14**. Presentations take the form of standard form summary sheets, each comprising five data groupings as follows:

I. Transit Particulars

This part specifies the particular data sub-set used to define the ice regime. The regime is numbered, and date, time and geographic coordinates of start and end points are provided. Total time, total distance travelled, course and speed made good between end points is also given.

Reference notes as may be relevant to the interpretation of results are included.

II. Meteorological Particulars

Weather conditions for each sub-regime are summarized, including average air temperature, visibility, precipitation and winds. Data are based on regular hourly observations.

III. Ice Conditions

The description of ice conditions is based on hourly observations which form a continuous record of ice conditions transitted by ROSSIA. Data include averages for ice types and concentration, predominant floe size, surface melt and thaw holes, degree of ridging and rubble, consolidation and convergence.

In addition, average values are presented for level ice thickness measurements made using downward looking 35 mm and video photography. The data are based on hourly point sample observations, and do not necessarily represent a continuous record within the route segment.

IV. Tactical Navigation

This portion describes the results of tactical navigation as indicated by transit mode (ie. percent time breaking ice in a continuous cusping fashion, etc.), and vessel manoeuvres.

V. Vessel Performance

This section provides descriptive statistics calculated for performance variables including total reactor power level, combinator setting, propeller speed, and ship speed. These data are based on hourly point sample records.

In addition, data are presented for hourly speed made good, which provide a continuous index of performance.

5.3.3 Results and Discussion

Selected results of the route segment analysis are presented in **Table 5.3**. This table includes the average values of key trafficability indicators recorded hourly for all fourteen data sub-sets, enabling a direct comparison between route segments.

In this table, variables describing ice conditions, vessel navigation and performance are presented in two groupings. The first group includes those variables based on continuous observation during the hour preceding individual data records. The second group includes those variables based upon the regular hourly point sample observations.

Both groupings begin with ship speed. It is seen that the point sample values for this variable are consistently 1-2 knots greater than the continuous record values. This is to be expected, given that the hourly Speed Made Good (SMG) is calculated as the rhumb line between hourly ship positions, and as such does not recognize the potential increase in distance travelled resulting from frequent course alterations.

Overall, average SMG varied from a high of 15 knots in 6-9 tenths ice, to a low of 8.1 knots in 9+ tenths, moderately pressured ice (full open water speed was 19 knots). Above 8 tenths total ice, reactor power was held in the range of 90-100%, with continuous full power applied while operating in moderate pressure. Heavy pressure, which might have been indicated by 10 tenths pack or active natural ice deformation, was not observed during the voyage.

The ice observed in route segments A and B was primarily first-year ice in an advanced state of decay, and in segments L, M and N, it was predominantly second-year ice in an earlier state of decay. Otherwise, ice conditions encountered were multi-year ice in initial decay, having average level component thicknesses ranging from 159 to 209 cm.

As discussed earlier, navigators were quite successful in avoiding vast and giant (and presumably thicker) multi-year ice floes, often following lighter ice conditions (leads and smaller floes) around their perimeter. The effect of this operation is apparent in the transit mode values, the definitions for which appear in Appendix A. For regimes of 9 or more tenths ice, the percentage of time spent in open water and pushing combined ranged from 0 to 16%, with the lower values corresponding to segments characterized by light to moderate pressure. (The exception to this was route segment I, for which the combined

Table 5.3
Summary of Trafficability Data for Route Segments A through N

Route Segment No.:	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Continuous Record Data:														
Speed Made Good (knots):	15.0	15.0	13.5	11.5	9.5	9.1	9.2	8.1	9.7	10.3	12.1	13.0	13.5	14.0
Ice Conc'n (tenths)														
Total:	6-9	~6-9	8-10	9	9	9-9+	9-9+	9+	9	9	8-9	8-9	9+	7
Multi-Year:	-	-	-	8	9	9-9+	9-9+	9+	9	9	8-9	-	-	-
Second-Year:	-	-	4-5	-	-	-	-	-	-	-	-	8-9	9+	5
First-Year:	6-9	~6-9	4-5	1	-	-	-	-	-	-	-	-	-	2
Melt Ponds (%):	18.	46.	39.	20.	17.	19.	20.	16.	16.	22.	20.	11.	25.	28.
Thaw Holes (%):	5.	19.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	8.
Ridges/Rubble (%):	55.	1.	15.	62.	13.	17.	7.	16.	14.	18.	11.	18.	15.	9.
Ice Pressure (L/M/H):	-	-	-	-	L	M	L-M	M	-	-	-	-	-	-
Transit Mode (% time)														
Open:	100.	88.	29.	7.	2.	0.	3.	0.	1.	8.	41.	18.	0.	35.
Push:	0.	10.	18.	9.	4.	1.	0.	0.	79.	4.	8.	4.	15.	5.
Break:	0.	2.	52.	75.	92.	95.	94.	88.	19.	88.	51.	78.	85.	60.
Other:	0.	0.	1.	9.	2.	4.	3.	12.	1.	0.	0.	0.	0.	0.
Point Sample Data:														
Ship Speed (knots):	16.5	16.6	14.5	12.7	11.1	10.9	10.1	9.6	12.2	11.6	13.4	13.8	16.5	15.0
Ice Thickness (cm):	n/a	<150.	128.	159.	163.	190.	207.	209.	207.	198.	185.	210.	115.	140.
Reactor Power (%):	55.	55.	64.	90.	92.	100.	100.	100.	96.	100.	91.	90.	90.	75.
Combinator (0-20):	19.	16.	19.	20.	20.	17.	20.	20.	20.	20.	16.	18.	18.	20.
Propeller Speed (rpm):	145.	126.	114.	145.	137.	140.	146.	150.	150.	136.	135.	149.	157.	157.

value of 80% open/pushing reflects the fact that the vessel was following her inbound track south from the pole).

Accounting for outside influencing factors such as temporary stops for mechanical repairs, the highest value found for the other/ramming transit mode was 12% for route segment H. This segment, northbound between 88°10' and 89°46' N, was characterized by moderate pressure the force of which slowed the vessel considerably, occasionally to a near stand-still. At these times the vessel would be reversed a short distance and a ram would be initiated in order to maintain an acceptable rate of forward progress. Rams were made at relatively low impact speeds of around 4 knots, and in most cases the vessel would continue to accelerate after impact, initially to a speed of 7-8 knots.

Ice decay ranged from advanced melt in the southern regions (segments A, B and N), where average thaw hole values reached 19% of ice floe surface area, to initial melt in the northern regions, where no thaw holes were observed and melt pond coverage was as little as 11%. There was no significant snow cover, however it appeared that the surface layer of most of the ice was snow-ice of varying thickness. In the more northerly regions, a layer of crusty snow 10-20 cm thick was not uncommon. Throughout the voyage the ice appeared relatively warm, and measurements made at the North Pole found through-thickness profile temperatures to lie within the range 0 to -3°C. (These data are reported in the following sub-section).

Ridging and rubble were highly variable throughout the voyage, as indicated by the statistics in the summary tables of Appendix E. Hummocks were observed only very rarely, and by far the majority of ridges were only lightly weathered, indicating in the case of multi-year ice, relatively young ages of perhaps only a few years. Sail heights were most commonly 1-2 m, but often reached 3-4 m. Averaged over the various route segments, ridging/rubble surface coverage values were consistently in the 10-20% range. The exceptions to this were segment A, where the rubble (55%) was comprised primarily of first and second-year brash ice, and segment D, where about one third of the 62% rubble was fresh and unconsolidated, and likely caused by a recent heavy pressure event.

5.4 Ice Physical Properties at the North Pole

Only one opportunity was provided to disembark the vessel and collect ice properties data. This was at the North Pole, where direct measures of ice thickness and snow cover, and ice temperature and salinity profiles were collected at three locations on one ice floe. **Table 5.4** presents the measured ice properties data.

At site 1, it was not possible to complete the thickness hole because the drill auger was unable to penetrate the heavy, slushy ice encountered after the 5 m depth. This unconsolidated material is a common characteristic of ridges, and its presence 50 m away from the edge of a 3 m ridge sail indicates that the ridge keel was, as expected, significantly wider than the sail. The coldest point measured was half way through the consolidated 5 m thickness, at 240 cm depth, and was -2.8°C. Otherwise, values ranged from -0.5 to -1.8°C.

Table 5.4

Ice Physical Properties Data
Geographic North Pole - August 8, 1990

Site No.	Location	Snow Cover (cm)	Ice Thickness (cm)	Through-Thickness Profile Depth (cm)	Through-Thickness Profile Temperature (C)	Through-Thickness Profile Salinity (ppt)
1	about 50m away from a 2-3m ridge	16	>6m	snow srfc	-0.5	
				snow/ice	-0.6	n/a
				60cm	-0.7	
				120	-1.8	
				180	-1.3	
				240	-2.8	
				300	+0.7 (slushy, bad data)	
2	level ice between two large melt ponds	14-30	260	snow srfc	-0.2	
				snow/ice	-0.1	0.0
				60cm	-0.3	1.0
				120	-0.1	1.0
				180	-0.1	1.0
3	near site 2	7-8	354	snow srfc	-0.2	
				snow/ice	-0.3	
				60cm	-0.3	0.0
				120	-0.5	2.0
				180	-0.9	2.0
				240		8.0
				sea water	-1.6	36.0

Sites 2 and 3 were about 100 m away from site 1, in the centre of the level portion of the floe. Thickness were 260 and 354 cm, respectively. Temperatures through both profiles ranged from -0.1 to only -0.9°C. The sea water temperature was -1.6°C.

The warmth of the ice at such a northerly latitude, and the fact that it was very similar in appearance to the majority of the multi-year ice encountered north of 85° N, supports the observation that the ice encountered throughout the voyage was relatively warm and weak.

Plate 5-1 Measuring Ice Physical Properties at the North Pole
August 8, 1990

6.0 CONCLUSIONS

At 0900 GMT on August 8, 1990 the Soviet nuclear icebreaker ROSSIA reached 90^0 N latitude. During the voyage, data were collected describing: Arctic Ocean ice and environmental conditions north of the USSR; Soviet ice navigation techniques and technologies; the nuclear icebreaker ROSSIA; and the icebreaking performance of ROSSIA. Following are the main conclusions of the study:

Ship Particulars

1. ROSSIA is a triple screw, 55 000 kW turbo-electric icebreaker having gross registered tonnage of 20 664 tonnes, an overall length of 150 m, beam of 30 m and draft of 11 m.

   Primary power is provided by two nuclear reactors. Eight heat exchangers convert heat from a high pressure hot water loop to a steam loop. Two 27.5 MW steam turbines operating at 3 600. rpm each power three 780 V, 6 phase AC generators. Power is converted to DC for the three 1 000 V, 17.6 MW dual armature DC motors, one for each propeller screw. The propellers are each 5 m in diameter.

2. The vessel was constructed with four special icebreaking features as follows:

   - air bubbler system
   - trim and roll system
   - shell plate heating system
   - ice piece deflectors (hull appendages)

   Of these features only the air bubbler system is used operationally. The bubblers, which may draw as much as 10% of total ship power, are considered to be a very important contributor to the vessels icebreaking capability.

   The trim and roll system was not found to be of much use in normal operations, however it is useful for adjusting ship's trim during stem-to-stern towing. The shell plating heating system has never worked, and the ice piece deflectors were removed from the hull structure after they were found to be ineffective in clearing away broken ice pieces, and were easily damaged.

3. In open water, ROSSIA was able to maintain a cruising speed of 19 knots at 55% of total reactor power. The results of earlier sea trials are presented in the report, and include data for turning circles, crash stops, draft changes, etc.

Ice Information and Navigation

4. The primary sources of data used by the Soviets to produce ice analysis and ice forecast information products are low resolution (4 km) visual, infra-red (NOAA, METEOR) and active microwave (Side Looking Airborne Radar - SLAR) satellite sensors, as well as higher resolution (30 m) airborne SLAR and airborne visual reconnaissance.

5. Technology for delivering ice forecast products to ship's at sea is not well developed. ROSSIA did not carry any means of receiving satellite data directly, nor of receiving airborne SLAR data (other than a physical delivery of hardcopy imagery to the ship). The ship was not equipped with a marine facsimile receiver, and therefore the only forecast/analysis products received were those delivered from a shore station in one helicopter trip.

6. The main ice navigation support tool were the two Visual Flight Rule (VFR) helicopters carried on board the ship. Prior to entering the multi-year pack ice, long-range reconnaissance missions lasting sometimes several hours were conducted from which observed charts were produced. The Soviets used their own coding methods for annotating ice conditions, which were different from the internationally recognized World Meteorological Organization (WMO) egg code.

   Once in the heavy pack ice, the aircraft were flown on a virtually continuous basis to search out and guide the vessel through the lightest possible ice conditions (subject to weather, refuelling, crew changes etc.). This technique was seen to be very effective in routing the vessel around the perimeter of vast and giant floes, through leads and smaller floe sizes.

Ice Conditions and Vessel Performance

7. Transit particulars, meteorological particulars, ice conditions, tactical navigation and vessel performance were documented on a 24-hour basis while operating in ice infested waters. Data were logged using a personal computer and a relational data base software package, which was used to analyze trafficability data.

8. Shipboard observations of ice edges and total ice concentrations corresponded well with passive microwave satellite data products produced by the Centre for Research in Earth and Space Science (CRESS), within the limits of the sensor resolution (25 km).

9. The main pack ice lay north of 80° N, and was comprised of multi-year ice in a state of initial decay, with extensive surface melt but no thaw holes, except in the more southerly regions. The larger (vast and giant) and probably heavier floes were avoided, with the result that from the shipboard perspective, ice conditions were consistently 9 tenths total coverage, increasing to 9+ tenths during extended periods of light to moderate pressure experienced during the northbound leg.

Most of the ice transitted by the vessel was relatively young, perhaps only a few years old, as indicated by relatively unweathered ridges and rubble, and the absence of well-defined surface drainage patterns. Ice thickness data derived from calibrated downward-looking photography averaged in the range 159 to 209 cm for level, undeformed ice floes. Ice properties data collected at the North Pole found the internal temperature of one level ice floe to lie in the range -0.1 to -0.9°C.

10. Average speed made good varied from a high of 15.0 knots in 6-9 tenths ice to a low of 8.1 knots in 9+ tenths, moderately pressured ice. Some ramming was occasionally required to loosen the ship, particularly when pressure was being experienced. However, the typical reversing distance was only about 100 m and impact speed was therefore relatively slow, usually around 4 knots. This was most often sufficient to "free" the vessel, and she would continue to accelerate through the ram.

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Appendix A

Trafficability Database Entry Field Definitions, Criteria and Coding

Appendix A

Trafficability Database Ebtry Field Definitions, Criteria and Coding

FIELD TITLE	DEFINITION	FIELD LENGTH	VALUE RANGE / CODING	ENTRY CRITERIA AND DETAILS
DATE	yy/mm/dd	8	integer	Date at time of observation.
NAME	Vessel Name	15	text	Name of vessel.
ENUM	Entry No.	3	integer	Each single or grouped observation is numbered in ascending order, beginning with number 1, the first observation for a particular voyage.
TYPE	Entry Type	1	H	Indicates that the data in that record of the log contains a series of ice and environmental condition observations, made are made at regular 60 min. intervals.
			E	Indicates that the data in that record, and any following records identified by the same entry number, constitutes the description of an event. Events are recorded on an ongoing basis as they occur.
REF	Reference	3	YES	Indicates that additional information outside of that contained in the database exists for a particular event. This information is recorded in the OBSERVATION LOG DIARY, with entries corresponding to the appropriate event number.
GMT	Grenwich Mean Time	4	integer	Time at which data in a particular record was observed.
NAVIGATION				DATA COLLECTED IN CONJUNCTION WITH THE REGULAR 60 min. ICE AND ENVIRONMENTAL CONDITION OBSERVATION:
LAT	Latitude (north)	4	integer	Ships positionfrom GPS.
LONG	Longitude (west)	5	integer	Ships position from GPS.
COURSE	Compass Heading	3	integer	Ships heading as given by helm order.
SPEED	Knots	2	integer	Ship speed as given by SatNav.

Appendix A

Trafficability Database Entry Field Definitions, Criteria and Coding

FIELD TITLE	DEFINITION	FIELD LENGTH	VALUE RANGE / CODING	ENTRY CRITERIA AND DETAILS
CMG	Course Made Good	3	integer	Using ships position data, these values are internally calculated by the database software for the preceeding 60 min. interval.
DMG	Distance Made Good	3	integer	
METORO- LOGICAL				DATA COLLECTED IN CONJUNCTION WITH THE REGULAR 60 min. ICE AND ENVIRONMENTAL CONDITION OBSERVATION:
WAVEHT	Wave Height	2	integer	Average amplitude of waves or swell, in meters.
DRY	Dry Bulb Temperature	5	decimal	In degrees celsius.
WINDSPD	Wind Speed	2	integer	True values of wind speed (knots) and direction, calculated from anemometer readings.
WINDDIR	Wind Direction	3	integer	
SKYCOV	Cloud Cover	1	0 - 9	Tenths of cloud cover based on visual observation.
			O	Overcast.
			X	Visual observation impossible due to fog or darkness.
SKYPRE	Precipi-tation	2		Based on predominant condition over preceeding 60 min. interval.
			R	Rain
			W	Showers
			L	Drizzle
			F	Fog
			S	Snow
			Z	Freezing Precipitation
VIS	Prevailing Visibility	1		Based on the observers judgement visibility is updated whenever a change is noted. Due to fluctuations common in reduced visibility situations, as well as their impact on navigational responses, visibility ranges are grouped and coded as follows:

Trafficability Database Entry Field Definitions, Criteria and Coding

FIELD TITLE	DEFINITION	FIELD LENGTH	VALUE RANGE / CODING	ENTRY CRITERIA AND DETAILS
			1	0 - 1/8 n.mi.
			2	> 1/8 - 1/2 n.mi.
			3	> 1/2 - 6 n.mi.
			4	> 6 n.mi.
			5	Dusk/dawn or flat light conditions.
			6	Darkness illuminated by moon and starlight.
			7	Darkness.
COVER	SEA ICE COVER			COVERAGE OF SEA SURFACE IN TENTHS, BASED ON AVERAGE CONDITIONS ENCOUNTERED DURING PRECEEDING 60 minutes: Swath width for observation is a minimum of 3 n.mi. to either side of the vessel (higher for low concentrations) unless reduced by poor visibility.
TOT	Total Cover	2		
N	New Ice	2		New ice forms up to light nilas (10 cm).
G	Grey Ice	2		10 - 15 cm.
GW	Grey-White	2		15 - 30 cm.
FY	First Year	2		30 cm - 2 m.
OI	Old Ice	2		Includes second-year and multi-year ice.
				FOR ALL SEA ICE COVER FIELDS:
			0 - 10	Tenths of Coverage (For 9+ use 9, with sum of partial concentrations = 10)
			FI	Fast Ice
			TR	Trace
			OW	Open Water
			BW	Bergy Water
			IF	Ice Free
FLOE SIZE				Predominant floe size over preceeding 60 min.
	FY min	1		
	FY max	1		
	OI min	1		
	OI max	1		

Appendix A

Trafficability Database Entry Field Definitions, Criteria and Coding

FIELD TITLE	DEFINITION	FIELD LENGTH	VALUE RANGE / CODING	ENTRY CRITERIA AND DETAILS
			0	Pancake
			1	Brash
			2	Ice Cake
			3	Small Floe ([illegible] - 100 m diameter)
			4	Medium Floe (100 - 500 m)
			5	Big Floe (500 - 2000 m)
			6	Vast Floe (2 - 10 km)
			7	Giant Floe (> 10 km)
			8	Fast Ice
THICK			integer	Estimated ice thickness (cm) over preceeding 60 min.
	FY min	1		
	FY max	1		
	OI min	1		
	OI max	1		
MELT	Melt	2	integer	Percent of ice surface covered by melt water.
THAW	Thaw	2	integer	Percent of ice floe area which is thaw holes.
RIDG	Ridge	2	integer	Percent of ice surface covered by ridges/rubble having a minimum sail height of 1.0 m.
ICEBREAKING				THE APPROXIMATE PORTIONS OF THE PRECEEDING 60 minutes IN WHICH THE VESSEL WAS ENGAGED IN THE FOLLOWING MODES OF TRANSIT THROUGH ICE INFESTED WATERS:
OPEN	% Time	2	integer	No contact with ice.
PUSH	% Time	2	integer	Pushing through ice floes, including impacts which result in immediate floe fracture.
BREAK	% Time	2	integer	Active breaking of ice in a cusping fashion.
OTHER	% Time	2	integer 99	Reverse/Ram cycles resulting in much reduced progress. Stopped.

Appendix A

Trafficability Database Entry Field Definitions, Criteria and Coding

FIELD TITLE	DEFINITION	FIELD LENGTH	VALUE RANGE / CODING	ENTRY CRITERIA AND DETAILS
MULTIPLE	No. Identical Impacts Since Last Record	2	integer	Multiple Rams.
PERFORM				ON-HOUR RECORDS OF VESSEL PERFORMANCE:
POWER	Reactor Power	2	integer	Percent of maximum nuclear reactor power being generated.
CONTROL			integer	Combinator control setting (0-20):
	Control #1	2		Port side propeller.
	Control #2	2		Centre propeller.
	Control #3	2		Starboard side propeller.
RPM			integer	Propeller shaft speed (rpm):
	rpm #1	2		Port side propeller.
	rpm #2	2		Centre propeller.
	rpm #3	2		Starboard side propeller.
PHOTO	Photography Record			USED TO RECORD A SINGLE OR SERIES OF PHOTOGRAPHS RELATING TO A PARTICULAR EVENT:
FILM	Film No.	2	integer	
FRAMEST	First Frame	2	integer	
FRAMEFN	Last Frame	2	integer	
NAV AIDS	Aids to Navigation			A RECORD OF THE UTILIZATION OF NAVIGATIONAL AIDS, UPDATED WHENEVER CHANGED:
R1	Radar 1	3	OFF	Radar is turned off.
R2	Radar 2	3	integer	Radar is turned on and set at indicated range.
LTS	Foreward Search-Lights	3	ON OFF	Indicates operational status.

Appendix B

Trafficability Data Reports

Appendix B

Trafficability Data Reports

List of Tables

Table No.	Title
B.1	Hourly and Event Transit Particulars
B.2	Predominant Ice Conditions Over Past Hour
B.3	Hourly Performance Particulars
B.4	Observation Log Reference Diary

Table B.1 Hourly and Event Transit Particulars

Date (yy/mm/dd)	Event No.	Event Type	Time (GMT)	Reference Log Entry	Position Latitude (ddmm N)	Position Longitude (dddmm E)	Course	Speed (knots)	35mm Photography Film No.	First Frame	Last Frame	Air Temp. Dry Bulb (C)	Wind Speed (knots)	Wind Direction	Wave Height (m)	Cloud Cover (tenths/ overcast)	Precipitation Code	Visibility Code	Marine Radar Range Unit #1 (n.mi.)	Unit #2 (n.mi.)
90/08/02	1	H	0500	Y	7633	6905	130	19	22	1	4				0	0		6	OFF	OFF
90/08/02	2	H	0600	Y	7644	7018	119	14	22	5	7				0	5		6	OFF	OFF
90/08/02	3	E	0640	Y					2	9	12							6	OFF	OFF
90/08/02	4	H	0700	Y	7641	7055			2	13	24				0			6	OFF	OFF
90/08/02	5	E	0733		7639	7119	70	14							0	0	-5	6	OFF	OFF
90/08/02	6	H	0800		7644	7200	113	20							0	0		6	OFF	OFF
90/08/02	7	H	0900		7623	7247	156	20							0	0		6	OFF	OFF
90/08/02	8	E	0913	Y					3	1	3							6	OFF	OFF
90/08/02	9	H	1000		7607	7326	151	19	22	13	15				0	8		6	OFF	OFF
90/08/02	10	E	1033		7601	7340	136	19								8		6	OFF	OFF
90/08/02	11	H	1100		7553	7454	140	18	22	16	19				0	8		6	OFF	OFF
90/08/02	12	H	1200		7530	7532	140	19	22	20	22	-1.0			0	8		6	OFF	OFF
90/08/02	13	H	1300		7523	7520	140	19	22	23	26	-1.0			0	0		6	OFF	OFF
90/08/02	14	H	1400		7503	7620	141	20							0	0		6	OFF	OFF
90/08/02	15	H	1500		7451	7658	139	19				1.0			1	0		6	OFF	OFF
90/08/02	16	H	1600		7430	7730	140	19				0.0			1	0		6	OFF	OFF
90/08/02	17	H	1700		7421	7819	140	20				1.0			1	0		6	24	OFF
90/08/02	18	E	1707															6	24	OFF
90/08/02	19	H	1800		7411	7912	106	20				0.0			1	0		6	24	OFF
90/08/02	20	E	1830		7410	7935	75	19	3	4	5							6	24	OFF
90/08/02	21	E	1842															6	24	OFF
90/08/02	22	H	1900		7412	8000	72	19				0.0			1	0		6	24	6
90/08/02	23	E	1920	Y				19										6	24	6
90/08/02	24	H	2000		7417	8057	126	16	3	6		-1.0			0	0		6	24	6
90/08/02	25	E	2037													0	-5	3	24	6
90/08/02	26	E	2048	Y			67											6	24	6
90/08/02	27	H	2100		7416	8150	101	19				-1.0			0	0		6	24	6
90/08/02	28	E	2116	Y	7413	8218	93	20	22	29	34					0	8	6	24	6
90/08/02	29	E	2130		7410	8226	75	20								0		6	24	6
90/08/02	30	E	2145	Y					3	7	13							6	24	6
90/08/02	31	E	2150	Y	7410	8208			22	33	36							6	24	6
90/08/03	32	E	0210	Y	7410	8206			23	2	7					0	8F	3	24	6
90/08/03	33	E	0234	Y														3	24	6
90/08/03	34	E	0254	Y	7410	8268	20	12	3	16	17							6	OFF	6
90/08/03	35	H	0300		7410	8236	77	10	23	18	13	2.0			0	0		6	OFF	6
90/08/03	36	E	0331	Y					3	21	24							6	OFF	6
90/08/03	37	E	0348	Y	7420	8310			3	23								6	OFF	6
90/08/03	38	H	0400		7422	8310	6	13				0.0			0	0		6	OFF	6
90/08/03	39	E	0433	Y														6	OFF	6
90/08/03	40	H	0500		7420	8333	40	11				0.0			0	0		6	OFF	10
90/08/03	41	E	0504	Y					3	20	27							6	OFF	10
90/08/03	42	E	0514	Y					3	28	27							6	OFF	10
90/08/03	43	E	0519						23	30								6	OFF	10
90/08/03	44	H	0600	Y	7420	8402	30	8				0.0			0	0		6	OFF	OFF
90/08/03	45	E	0620				40											6	OFF	OFF
90/08/03	46	E	0645	Y														6	OFF	OFF
90/08/03	47	E	0653	Y														6	OFF	OFF
90/08/03	48	H	0700		7400	8420	303	8				1.0			0	0		6	OFF	OFF
90/08/03	49	H	0800	Y	7434	8402	25	10				0.0			0	0		6	OFF	6
90/08/03	50	H	0900		7401	8545	75	10				0.0			0	8		6	OFF	OFF

Table B.1 Hourly and Event Transit Particulars

Date (yy/mm/dd)	Event No.	Event Type	Time (GMT)	Reference Log Entry	Position		Course	Speed (knots)	35mm Photography			Air Temp. Dry Bulb (C)	Wind		Wave Height (m)	Cloud Cover (tenths/ overcast)	Precipitation Code	Visibility Code	Marine Radar Range	
					Latitude (ddmm N)	Longitude (dddmm E)			Film No.	First Frame	Last Frame		Speed (knots)	Direction					Unit #1 (n.mi.)	Unit #2 (n.mi.)
90/08/03	51	E	0920	Y	7304	8612		0										4	OFF	OFF
90/08/03	52	H	1000		7304	8612	35	4				6.0			0	9		4	OFF	OFF
90/08/03	53	E	1044		7511	8634	81	12				4.0				9		4	OFF	12
90/08/03	54	H	1100		7514	8653	11	19				4.0			0	8		4	OFF	12
90/08/03	55	H	1200		7524	8743	42	16				1.0			0	6		4	OFF	OFF
90/08/03	56	E	1245	Y				0										4	OFF	OFF
90/08/03	57	H	1300	Y	7529	8815	44	18				1.0			0	0	S	4	OFF	OFF
90/08/03	58	H	1400	Y	7536	8912	90	5				1.0			0	8		4	OFF	OFF
90/08/03	59	E	1405	Y					4	[illegible]	6							4	OFF	OFF
90/08/03	60	H	1500	Y	7550	8946	11	18				2.0			0	8		4	OFF	OFF
90/08/03	61	E	1645	Y														4	OFF	OFF
90/08/03	62	H	1700	Y	7600	9122	106	14	4	7		2.0			0	8		4	OFF	OFF
90/08/03	63	E	1740	Y					4	8								4	OFF	OFF
90/08/03	64	E	1745	Y				15										4	OFF	OFF
90/08/03	65	H	1800		7559	9212	36	15	4	9		1.5			0	0	S-	4	OFF	OFF
90/08/03	66	E	1801						24	17	19							4	OFF	OFF
90/08/03	67	E	1830	Y					4	10								4	OFF	OFF
90/08/03	68	H	1900		7609	9310	60	15				1.5			0	0		4	OFF	OFF
90/08/03	69	E	1903	Y				0										4	OFF	OFF
90/08/03	70	H	2000		7612	9330	90	15				1.0			0	0		4	OFF	OFF
90/08/03	71	E	2030	Y														4	OFF	OFF
90/08/03	72	H	2100	Y	7618	9442	61	17				[illegible]			0	8		4	OFF	OFF
90/08/03	73	H	2200	Y	7626	9340	60	16				1.0			0	9		4	OFF	OFF
90/08/03	74	E	2225	Y	7629	9609	80	19										4	OFF	OFF
90/08/03	75	H	2300	Y	7633	9646	91	18				4.0			0	8		4	OFF	OFF
90/08/03	76	E	2320	Y					24	22	24							4	OFF	6
90/08/04	77	H	0035	Y	7631	9824		18	24	25	26	4.0			0	1		4	OFF	6
90/08/04	78	H	0100	Y	7635	9842	349	17	24	27	35	4.0			0	1		4	OFF	6
90/08/04	79	H	0200	Y	7644	9922	42	17				4.0			0	2		4	OFF	6
90/08/04	80	E	0235	Y				17	4	11	12							4	OFF	6
90/08/04	81	H	0300		7657	9939	51	16				6.0			0	1		4	OFF	OFF
90/08/04	82	E	0332	Y					4	13	14							4	OFF	OFF
90/08/04	83	H	0400		7708	10035	35	17				6.0			0	1		4	OFF	OFF
90/08/04	84	H	0500		7721	10136	50	15				6.0			0	3		4	OFF	OFF
90/08/04	85	E	0510	Y				0	4	16	18							4	OFF	OFF
90/08/04	86	E	0525															4	OFF	OFF
90/08/04	87	E	0545	Y					4	19	25							4	OFF	OFF
90/08/04	88	H	0600		7730	10213	48	16				7.0			0	5		4	OFF	OFF
90/08/04	89	H	0700		7741	10313	59	17				7.0			0	4		4	OFF	OFF
90/08/04	90	H	1100		7750	10801	94	8				4.0	21	45	0	0		4	OFF	OFF
90/08/04	91	H	1200	Y	7802	10840	319	12	26	9	16		21	45	0	0		4	OFF	OFF
90/08/04	92	E	1237		7810	10817	332	17	26	19	21	2.5				0		4	OFF	OFF
90/08/04	93	H	1300	Y	7817	10818	355	18	26	22		3.0	21	45	0	0	R	4	OFF	OFF
90/08/04	94	H	1400	Y	7830	10839	33	17				4.0	19	45	0	0		4	OFF	OFF
90/08/04	95	H	1500		7845	10912	26	17				4.0	19	45	0	0	R-	4	OFF	OFF
90/08/04	96	H	1700	Y	7911	10906	359	8	4	26		3.0	21	45	0	0	R	4	OFF	OFF
90/08/04	97	E	1720															3	OFF	OFF
90/08/04	98	H	1800		7926	10903	338	15	4	27		3.0	21	45	0	0	R-	3	OFF	OFF
90/08/04	99	H	1900		7936	10828	340	9	4	28		3.0	21	45	0	0		4	OFF	OFF
90/08/04	100	E	1930	Y	7942	10825			4	33	35							4	OFF	OFF

Table B.1 Hourly and Event Transit Particulars

Date (yy/mm/dd)	Event No.	Event Type	Time (GMT)	Reference Log Entry	Position Latitude (ddmm N)	Position Longitude (dddmm E)	Course	Speed (knots)	35mm Photography Film No.	35mm Photography First Frame	35mm Photography Last Frame	Air Temp. Dry Bulb (C)	Wind Speed (knots)	Wind Direction	Wave Height (m)	Cloud Cover (tenths/ overcast)	Precipitation Code	Visibility Code	Marine Radar Range Unit #1 (n.mi.)	Marine Radar Range Unit #2 (n.mi.)
90/08/04	101	H	2000		7940	10746	262	15	4	36	37	4.0	21	45	M	0		4	OFF	OFF
90/08/04	102	H	2100	Y	7937	10643	280	15	26	23	30	2.5	21	45	M	5		4	OFF	OFF
90/08/04	103	H	2200	Y	7939	10528	254	15	26	31	37	2.0	13	45	M	0		4	OFF	OFF
90/08/04	104	H	2300		7944	10416	282	14	27	1	9	5.0	9	90	M	0		4	OFF	OFF
90/08/05	105	H	0000		7949	10318	311	11	27	10	13	8.0	9	90	0	0		4	OFF	OFF
90/08/05	106	H	0100		7954	10227	327	13	27	14	21	6.0	8	90	0	0		4	OFF	OFF
90/08/05	107	H	0200		8001	10147	299	8	27	22	31	8.0	6	90	0	0		4	OFF	OFF
90/08/05	108	H	0300		8003	10051	249	14	5	1	2	5.0	6	90	0	0		4	OFF	OFF
90/08/05	109	H	0400		8011	9958	26	13				7.0	6	90	0	2		4	OFF	OFF
90/08/05	110	E	0413	Y				16										4	OFF	OFF
90/08/05	111	E	0433	Y	8018	9935		16	5	3	5							4	OFF	OFF
90/08/05	112	H	0500	Y	8022	9907	295	10	5	6		7.0	11	90	0	2		4	OFF	OFF
90/08/05	113	E	0515	Y				8										4	OFF	OFF
90/08/05	114	E	0550	Y				0										4	OFF	OFF
90/08/05	115	E	0916	Y	8024	9756	350	10	29	0	4	6.0				3		4	OFF	OFF
90/08/05	116	H	1000		8035	9810	52	16	29	5	9	7.0	23	90	0	0		4	OFF	OFF
90/08/05	117	H	1100		8046	9835	13	16	29	10		2.0	23	90	0	0		4	OFF	OFF
90/08/05	118	E	1112		8054	9820	320	10	29	11	14	2.0				0		4	OFF	OFF
90/08/05	119	E	1240		8110	9653	309	16	29	15	17	2.0				0		4	OFF	OFF
90/08/05	120	H	1300	Y	8113	9633	320	17				2.0	23	90	0	0		4	OFF	OFF
90/08/05	121	H	1400		8126	9537	313	16				2.0	23	90	0	2		4	OFF	OFF
90/08/05	122	E	1420		8130	9500	313	11										4	OFF	OFF
90/08/05	123	H	1500		8134	9419	329	10	5	9	12	3.0	11	90	0	1		4	OFF	OFF
90/08/05	124	H	1700		8158	9431	2	13	5	13	14	5.0	17	90	0	0		4	OFF	OFF
90/08/05	125	H	1800		8212	9441	28	14	5	15	17	4.0	17	90	0	0		4	OFF	OFF
90/08/05	126	H	1900		8223	9520	17	15	5	18	19	2.0	17	90	0	0		4	OFF	OFF
90/08/05	127	H	2000		8234	9555	46	15	5	20	21	2.0	17	90	0	1		4	OFF	OFF
90/08/05	128	E	2010	Y					5	22								4	OFF	OFF
90/08/05	129	E	2040															4	OFF	OFF
90/08/05	130	H	2100	Y	8244	9615	1	8	29	18	27	1.0	17	90	0	1		4	OFF	OFF
90/08/05	131	H	2200	Y	8251	9610	34	14	29	28	3	1.0	17	90	0	0		4	OFF	OFF
90/08/05	132	H	2300		8259	9608	339	3	30	4	12	1.0	17	90	0	0		4	OFF	OFF
90/08/06	133	H	0000	Y	8309	9626	12	13	30	13	21	1.0	17	90	0	0		4	OFF	OFF
90/08/06	134	H	0100		8319	9712	9	15	30	22	31	1.0	17	0	0	0		4	OFF	OFF
90/08/06	135	H	0200		8328	9807	26	10	30	32	37	2.0	17	0	0	0		4	OFF	OFF
90/08/06	136	H	0300	Y	8336	9852	12	10	5	23	27	4.0	17	0	0	0		4	OFF	OFF
90/08/06	137	H	0400	Y	8343	9853	0	14	5	28	30	3.0	17	0	0	0		4	OFF	OFF
90/08/06	138	E	0407	Y				0	5	31								4	OFF	OFF
90/08/06	139	H	0500	Y	8351	9929	45	14	5	32	35	4.0	19	120	0	0		4	OFF	OFF
90/08/06	140	H	0600		8400	10004	340	12	5	36	37	6.0	19	90	0	0		4	OFF	OFF
90/08/06	141	E	0648														P	2	OFF	OFF
90/08/06	142	H	0700	Y	8407	10109	70	9	6	1	5	5.0	19	90	0	M	P	3	OFF	OFF
90/08/06	143	E	0701						40	0	4							3	OFF	OFF
90/08/06	144	H	0800		8414	10035	322	11	6	6	8	7.0	19	90	0	M	P	3	OFF	OFF
90/08/06	145	H	0900	Y	8422	10012	0	13	40	5	10		19	90	0	M	P	3	OFF	OFF
90/08/06	146	H	1000		8431	9913	324	14				1.0	11	30	0	M	P	3	OFF	OFF
90/08/06	147	H	1100		8435	9849	325	12	40	11	18	1.0	11	30	0	M	P	3	OFF	OFF
90/08/06	148	H	1200		8439	9756						1.0	11	30	0	M	P	3	OFF	OFF
90/08/06	149	E	1201	Y				0										3	OFF	OFF
90/08/06	149	E	1500					0										3	OFF	OFF

Table B.1 Hourly and Event Transit Particulars

Date (yy/mm/dd)	Event No.	Event Type	Time (GMT)	Reference Log Entry	Position Latitude (ddmm N)	Position Longitude (dddmm E)	Course	Speed (knots)	35mm Photography Film No.	35mm Photography First Frame	35mm Photography Last Frame	Air Temp. Dry Bulb (C)	Wind Speed (knots)	Wind Direction	Wave Height (m)	Cloud Cover (tenths/ overcast)	Precipitation Code	Visibility Code	Marine Radar Range Unit #1 (n.mi.)	Marine Radar Range Unit #2 (n.mi.)
90/08/06	150	H	1600		8441	9601	275	14	6	29	31	1.0	11	30	0	7		4	OFF	OFF
90/08/06	151	H	1700		8439	9423	335	7	6	32		1.0	11	30	0	5		4	OFF	OFF
90/08/06	152	H	1800		8450	9305	337	14	6	36	38	3.0	9	30	0			4	OFF	OFF
90/08/06	153	H	1900	Y	8458	9240	298	10	7	1	2	2.0	15	30	0	0		4	OFF	OFF
90/08/06	154	H	2000		8506	9236	354	11	7	3		3.0	9	30	0	0		4	OFF	OFF
90/08/06	155	H	2100		8518	9257	353	12	40	19	28	0.0	9	30	0	0		4	OFF	OFF
90/08/06	156	H	2200		8527	9221	345	13	40	29	37	0.0	9	0	0	0		3	OFF	OFF
90/08/07	157	H	0000	Y	8550	9310	22	8	31	31	37	0.0	23	0	0	X	F	2	OFF	OFF
90/08/07	158	H	0100		8600	9440	41	14	32	0	12	0.0	23	0	0	X	F	2	OFF	OFF
90/08/07	159	H	0200		8610	9505	36	14	32	13	22	0.0	23	0	0	0	F	3	OFF	OFF
90/08/07	160	E	0240	Y					7	4	5							3	OFF	OFF
90/08/07	161	H	0300		8619	9540	20	10	7	6	9	3.0	17	0	0	0		3	OFF	OFF
90/08/07	162	H	0400		8629	9431	3	7	7	10	12	2.0	15	0	0	0	F	3	OFF	OFF
90/08/07	163	H	0500		8637	9458	319	15	7	15	17	3.0	4	0	0	0	F	3	OFF	OFF
90/08/07	164	H	0600		8645	9323	312	11	7	18	19	2.0	4	0	0	0	F	2	OFF	OFF
90/08/07	165	E	0640	Y	8649	9323		0										3	OFF	OFF
90/08/07	166	H	0900		8701	9318	299	13	32	23	33	1.0	4	0	0	0	F	3	OFF	OFF
90/08/07	167	H	1000	Y	8711	9338	6	11	32	34	37	0.0	17	0	0	0	F	3	OFF	OFF
90/08/07	168	H	1100		8716	9350	357	12	33	0	11		26	0	0	0	F	3	OFF	OFF
90/08/07	169	H	1200	Y	8725	9346	4	3	33	12	21	1.0	26	0	0	0	F	3	OFF	OFF
90/08/07	170	H	1300		8733	9400	38	12	33	22	35	1.0	32	0	0	0	F	3	OFF	OFF
90/08/07	171	H	1400		8742	9522	27	10	33	36	8	1.0	34	0	0	0	FR	3	OFF	OFF
90/08/07	172	H	1500	Y	8752	9659	354	13	7	20	21	1.0	32	0	0	0	FR	3	OFF	OFF
90/08/07	173	E	1630	Y														4	OFF	OFF
90/08/07	174	H	1700		8755	9725	251	2	7	22	24	1.5	38	0	0	0	FR	4	OFF	OFF
90/08/07	175	H	1800		8803	9541	19	11	7	26	30	1.5	39	90	0	0	S	4	OFF	OFF
90/08/07	176	H	1900		8810	9513	327	5	7	31	33	2.0	23	140	0	0	S	4	OFF	OFF
90/08/07	177	H	2000		8821	9521	346	10	7	34	38	2.0	24	120	0	0	S	4	OFF	OFF
90/08/07	178	H	2100	Y	8829	9420	330	5	34	9	19	1.0	32	110	0	0	S	4	OFF	OFF
90/08/07	179	H	2200		8834	9405	10	10	34	20	23	1.0	34	120	0	0	S	4	OFF	OFF
90/08/07	180	H	2300		8838	9451	7	10	34	24	29	1.0	32	100	0	0	S	4	OFF	OFF
90/08/08	181	H	0000		8844	9837	13	11	34	30	37	0.0	30	100	0	0	S	4	OFF	OFF
90/08/08	182	H	0200	Y	8900	10142	265	3	35	9	19	0.0	24	150	0	0	RS	4	OFF	OFF
90/08/08	183	H	0300	Y	8906	10537	50	9	8	1	2	2.0	23	100	0	0		4	OFF	OFF
90/08/08	184	H	0400		8914	11254	12	13	8	3		2.0	17	120	0	0		4	OFF	OFF
90/08/08	185	H	0600		8934	11209	323	11	8	4	7	2.5	6	120	0	0		4	OFF	OFF
90/08/08	186	H	0700		8946	10224	354	14	8	10	15	2.5	6	120	0	0		4	OFF	OFF
90/08/08	187	H	0800		8954	6629	351	11	8	16	19	2.0	8	0	0	0	S-	4	OFF	OFF
90/08/08	188	H	0900	Y	9000	0		2	35	20	23	0.0	11	0	0	9	S-	4	OFF	OFF
90/08/08	189	H	2110		9000								12			0		4	OFF	OFF
90/08/08	190	E	2130		8951	8801	173	11	35	24	28	1.0	11			0		4	OFF	OFF
90/08/08	191	H	2200		8952	10529	28	9	35	29	37	2.0	26	0	0	9		4	OFF	OFF
90/08/08	192	H	2300	Y	9000	0	197	13	37	29	37	2.0	26	0	0	9		4	OFF	OFF
90/08/09	193	H	0000		8950	11226	158	4	38	1	6	2.0	28	0	0	0		4	OFF	OFF
90/08/09	194	H	0100	Y	8942	11437	170	14	38	7	12	1.0	32	0	0	0		4	OFF	OFF
90/08/09	195	H	0200		8933	11720	235	15	38	13	30	2.0	36	0	0	9		4	OFF	OFF
90/08/09	196	H	0300	Y	8922	11641	218	15	8	25	29	2.0	32	0	0	0		4	OFF	OFF
90/08/09	197	H	0400		8914	10636	285	8	8	30		2.0	17	270	0	0		4	OFF	OFF
90/08/09	198	H	0500		8905	10440	113	12	8	31	34	1.0	30	270	0	0		4	OFF	OFF
90/08/09	199	H	0600	Y	8857	10489	218	13	8	35	36	2.0	20	300	0	0		4	OFF	OFF

Table B.1 Hourly and Event Transit Particulars

Date (yy/mm/dd)	Event No.	Event Type	Time (GMT)	Reference Log Entry	Position		Course	Speed (knots)	35mm Photography			Air Temp. Dry Bulb (C)	Wind		Wave Height (m)	Cloud Cover (tenths/ overcast)	Precipitation Code	Visibility Code	Marine Radar Range	
					Latitude (ddmm N)	Longitude (dddmm E)			Film No.	First Frame	Last Frame		Speed (knots)	Direction					Unit #1 (n.mi.)	Unit #2 (n.mi.)
90/08/09	200	M	0700		0849	9805	147	14	10	1		2.0	26	300	0	0		4	OFF	OFF
90/08/09	201	E	0730					6	10	2								4	OFF	OFF
90/08/09	202	M	0800		0837	9729	139	13	10	3		2.0	30	230	0	0		4	OFF	OFF
90/08/09	203	M	0900		0825	9504	112	10	30	21	30	2.0	32	230	0	0		4	OFF	OFF
90/08/09	204	M	1000		0816	9501	121	6	30	32	39	2.0	24	230	0	0		4	OFF	OFF
90/08/09	205	M	1100		0810	9343	260	14	39	0	6	2.0	24	230	0	0		4	OFF	OFF
90/08/09	206	M	1200		0802	9257	239	9	39	7	13	2.5	32	230	0	0	F	4	OFF	OFF
90/08/09	207	M	1300	Y	0754	9101	209	12	39	14	20	2.0	28	230	0	0	F	4	OFF	OFF
90/08/09	208	M	1400		0744	8736	203	10	39	21	28	2.0	24	230	0	0	F	4	OFF	OFF
90/08/09	209	M	1500	Y	0738	8548	216	15	10	4	6	1.5	24	180	0	0		4	OFF	OFF
90/08/09	210	M	1700		0722	8407	205	9	10	7	8	2.0	19	240	0	0		4	OFF	OFF
90/08/09	211	E	1749														F	3	OFF	OFF
90/08/09	212	M	1800		0714	8250	248	11	10	9	13	2.0	13	240	0	0	F	3	OFF	OFF
90/08/09	213	M	2000		0705	7828	203	13	10	14	17	3.0	13	240	0	9	F	2	OFF	OFF
90/08/09	214	M	2100	Y	0650	7523	153	12	39	29	37	1.0	21	240	0	7		4	OFF	OFF
90/08/09	215	M	2200		0645	7351	243	13	41	0	7	1.0	13	240	0	5		4	OFF	OFF
90/08/09	216	M	2300	Y	0633	7224	254	16	41	8	16	1.0	13	240	0	5		4	OFF	OFF
90/08/10	217	M	0000		0623	6912	295	15	41	17	25	0.0	11	240	0	0		4	OFF	OFF
90/08/10	218	M	0100		0617	6740	212	12	41	26	32	0.0	19	240	0	0	F	4	OFF	OFF
90/08/10	219	M	0200		0607	6536	284	20	41	33	37	2.0	13	240	0	9		4	OFF	OFF
90/08/10	220	M	0300	Y	0554	6405	215	10	10	18	20	2.5	15	180	0	9		4	OFF	OFF
90/08/10	221	M	0400		0546	6228	180	10	10	21		2.5	15	180	0	9		4	OFF	OFF
90/08/10	222	M	0500		0535	6150	155	13	10	22	24	3.0	17	180	0	0		4	OFF	OFF
90/08/10	223	M	0600		0522	6154	195	13	10	25		4.0	9	180	0	0	F	3	OFF	OFF
90/08/10	224	M	0700		0508	6139	210	9	10	26	27	3.0	15	180	0	0		4	OFF	OFF
90/08/10	225	M	0800		0501	6220	107	11	10	28	30	2.5	19	180	0	9		4	OFF	OFF
90/08/10	226	E	0813						10	31	32							4	OFF	OFF
90/08/10	227	M	0900		0448	6332	196	15	42	0	5	2.5	19	180	0	4		4	OFF	OFF
90/08/10	228	M	1000		0431	6402	178	13	42	6	12	2.0	19	180	0	8		4	OFF	OFF
90/08/10	229	M	1100		0422	6419	190	16	42	13	21	1.5	21	180	0	9		4	OFF	OFF
90/08/10	230	M	1200		0414	6426	165	14	42	22	30	2.0	23	180	0	0		4	OFF	OFF
90/08/10	231	M	1300		0358	6509	204	15	42	31	37	2.0	21	180	0	0	SF	4	OFF	OFF
90/08/10	232	M	1400		0352	6550	161	13	43	0	5	2.0	23	180	0	0	SF	3	OFF	OFF
90/08/10	233	M	1500		0343	6532	207	15	10	33	35	2.0	19	180	0	0	F	3	OFF	OFF
90/08/10	234	M	1600		0330	6521	150	16	10	36	37	1.0	23	180	0	0	F	2	OFF	OFF
90/08/10	235	M	1700		0317	6540	200	6	43	6		-1.0	19	250	0	0		4	3	OFF
90/08/10	236	E	1707	Y				0										4	3	OFF
90/08/10	237	M	1800	Y	0304	6544	165	11	43	7	8	-1.5	23	250	0	9		4	OFF	OFF
90/08/10	238	M	1900		0250	6555	187	17	43	9	10	-1.5	23	270	0	8		4	OFF	OFF
90/08/10	239	M	2000		0234	6558	167	18	43	11		-1.0	23	270	0	8		4	OFF	OFF
90/08/10	240	M	2100	Y	0220	6540	184	17				1.0	30	270	0	0	RF	4	OFF	OFF
90/08/10	241	M	2200		0207	6529	195	16	43	12	16	2.0	30	270	0	0	F	4	OFF	OFF
90/08/10	242	M	2300		0153	6523	174	16	43	17	20	1.0	30	270	0	0	F	4	OFF	OFF
90/08/10	243	E	2330															1	OFF	OFF
90/08/11	244	M	0000		0136	6534	176	11	43	21	31	1.5	26	270	0	0	F	1	OFF	OFF
90/08/11	245	M	0100		0130	6540	170	16	43	32	37	2.0	23	270	0	0	F	1	OFF	OFF
90/08/11	246	M	0200		0111	6549	197	17	44	0	2	2.0	23	270	0	0	F	1	OFF	OFF
90/08/11	247	E	0305	Y														1	OFF	OFF

Table B.2 Predominant Ice Conditions Over Past Hour

Date	Event No.	Event Type	Time	Reference Log Entry	Sea Ice Concentrations (Tenths)						Predominant Floe Size				Thaw Holes	Melt Ponds	First-Year Rubble	Ice Thickness Estimates			
					Total	New	Grey	Grey-White	First-Year	Old	First-Year Min.	First-Year Max.	Old Min.	Old Max.				First-Year Min.	First-Year Max.	Old Min.	Old Max.
(yy/mm/dd)			(GMT)												(%)	(%)	(%)	(cm)	(cm)	(cm)	(cm)
90/08/02	1	H	0500	Y	6	0	0	0	6	0	1	2			0	5	30	70	100	0	0
90/08/02	2	H	0600	Y	9	0	0	0	9	0	1	2			0	10	90	70	100	0	0
90/08/02	4	H	0700	Y	8	0	0	0	6	2	2	3	2	2	10	25	20	90	150	0	0
90/08/02	6	H	0800		3	0	0	0	2	1	2	3	2	2				90	150	0	0
90/08/02	7	H	0900		2	0	0	0	1	1	2	2	2	2				0	0	0	0
90/08/02	9	H	1000		1	0	0	0	1	0	1	2						0	0	0	0
90/08/02	11	H	1100		2	0	0	0	2	0	1	2						0	0	0	0
90/08/02	12	H	1200		3	0	0	0	3	0	1	2						50	100	0	0
90/08/02	13	H	1300		2	0	0	0	2	0	1	2						50	100	0	0
90/08/02	14	H	1400		OW	0	0	0	0	0						0	0	0	0	0	0
90/08/02	15	H	1500		TR	0	0	0	TR	0								0	0	0	0
90/08/02	16	H	1600		OW	0	0	0	0	0								0	0	0	0
90/08/02	17	H	1700		OW	0	0	0	0	0								0	0	0	0
90/08/02	19	H	1800		2	0	0	0	2	0	2	3						0	0	0	0
90/08/02	22	H	1900		3	0	0	0	3	0	2	3			5	25	5	0	0	0	0
90/08/02	24	H	2000		6	0	0	0	6	0	1	2			10	30	0	50	150	0	0
90/08/02	27	H	2100		4	0	0	0	4	0	1	2			10	30	0	0	0	0	0
90/08/03	35	H	0300		4	0	0	0	4	0	1	3			30	70	0	0	0	0	0
90/08/03	38	H	0400		5	0	0	0	5	0	2	3			30	70	0	0	0	0	0
90/08/03	40	H	0500		4	0	0	0	4	0	3	3			30	50	0	0	0	0	0
90/08/03	44	H	0600	Y	9	0	0	0	9	0	3	4			20	50	0	10	70	0	0
90/08/03	48	H	0700		2	0	0	0	2	0	1	2						0	0	0	0
90/08/03	49	H	0800	Y	1	0	0	0	1	0	1	2						0	0	0	0
90/08/03	50	H	0900		1	0	0	0	1	0	1	2						0	0	0	0
90/08/03	52	H	1000		TR	0	0	0	TR	0	1	1						0	0	0	0
90/08/03	54	H	1100		1	0	0	0	1	0	1	2						0	0	0	0
90/08/03	55	H	1200		1	0	0	0	1	0	1	3						0	0	0	0
90/08/03	57	H	1300	Y	2	0	0	0	2	0	1	3						0	0	0	0
90/08/03	58	H	1400	Y	7	0	0	0	7	0	1	3						0	0	0	0
90/08/03	60	H	1500	Y	3	0	0	0	3	0	1	2						0	0	0	0
90/08/03	62	H	1700	Y	8	0	0	0	8	0	4	5			10	50	0	40	70	0	0
90/08/03	65	H	1800		9	0	0	0	9	0	3	4			20	60	0	30	90	0	0
90/08/03	68	H	1900		9+	0	0	0	9	1	8	8	1	2	10	40	0	50	110	0	0
90/08/03	70	H	2000		8	0	0	0	4	4	8	8	8	8	10	40	0	40	90	0	0
90/08/03	72	H	2100	Y	10	0	0	0	5	5	8	8	8	8	5	30	10	60	140	0	0
90/08/03	73	H	2200	Y	10	0	0	0	5	5	8	8	8	8	5	60	5	60	140	0	0
90/08/03	75	H	2300	Y	10	0	0	0	5	5	8	8	8	8	5	60	5	0	0	0	0
90/08/04	77	H	0035	Y	1	0	0	0	1	0	1	8						0	0	0	0
90/08/04	78	H	0100	Y	8	0	0	0	4	4	8	8			10	40	5	60	140	0	0
90/08/04	79	H	0200	Y	9	0	0	0	5	4	8	8	8	8	5	30	5	40	140	0	0

Table B.2 Predominant Ice Conditions Over Past Hour

Date	Event No.	Event Type	Time	Reference Log Entry	Sea Ice Concentrations (Tenths)						Predominant Floe Size				Thaw Holes	Melt Ponds	First-Year Rubble	Ice Thickness Estimates			
(yy/mm/dd)			(GMT)		Total	New	Grey	Grey-White	First-Year	Old	First-Year Min.	First-Year Max.	Old Min.	Old Max.	(%)	(%)	(%)	First-Year Min. (cm)	First-Year Max. (cm)	Old Min. (cm)	Old Max. (cm)
90/08/04	81	H	0300		9	0	0	0	9	0	4	5			15	50	5	80	150	0	0
90/08/04	83	H	0400		10	0	0	0	10	0	8	8			10	40	0	60	120	0	0
90/08/04	84	H	0500		10	0	0	0	10	0	8	8			10	40	0	60	90	0	0
90/08/04	88	H	0600		5	0	0	0	5	0	2	3			10	30	5	0	0	0	0
90/08/04	89	H	0700		9	0	0	0	9	0	4	4			10	30	0	30	70	0	0
90/08/04	90	H	1100		1	0	0	0	1	0	2	3						0	0	0	0
90/08/04	91	H	1200	Y	9	0	0	0	6	3	3	4	2	3	10	30	0	0	0	100	200
90/08/04	93	H	1300	Y	2	0	0	0	1	1	2	3	2	2				0	0	0	0
90/08/04	94	H	1400	Y	5	0	0	0	3	2	2	3	2	2	0	25	10	0	0	0	0
90/08/04	95	H	1500		8	0	0	0	4	4	2	3	2	3	10	50	30	0	0	0	0
90/08/04	96	H	1700	Y	9	0	0	0	4	5	2	4	2	4	15	70	20	30	120	70	150
90/08/04	98	H	1800		9	0	0	0	6	3	3	4	2	4	10	50	20	30	120	70	200
90/08/04	99	H	1900		9	0	0	0	5	4	2	3	2	3	10	50	20	30	120	150	300
90/08/04	101	H	2000		9	0	0	0	4	5	2	3	2	3	5	25	15	40	120	70	150
90/08/04	102	H	2100	Y	9+	0	0	0	5	5	3	3	2	3	5	40	20	60	130	130	200
90/08/04	103	H	2200	Y	9+	0	0	0	5	5	8	8	8	8	5	30	35	80	130	130	200
90/08/04	104	H	2300		9+	0	0	0	4	6	8	8	8	8	5	30	35	80	120	120	200
90/08/05	105	H	0000		9	0	0	0	4	5	8	8	8	8	5	30	25	80	120	120	200
90/08/05	106	H	0100		10	0	0	0	4	6	8	8	8	8	5	20	25	80	120	120	200
90/08/05	107	H	0200		9	0	0	0	4	5	8	8	8	8	5	20	35	80	120	160	250
90/08/05	108	H	0300		9+	0	0	0	0	9+			2	3	5	30	60	0	0	120	250
90/08/05	109	H	0400		9	0	0	0	0	9			2	2	5	40	60	0	0	150	250
90/08/05	112	H	0500	Y	TR	0	0	0	0	TR	1	1			0	0	0	0	0	0	0
90/08/05	116	H	1000		9	0	0	0	6	3	8	8	8	8	0	10	10	70	120	150	250
90/08/05	117	H	1100		9	0	0	0	5	4	8	8	8	8	0	10	60	80	130	150	250
90/08/05	120	H	1300	Y	TR	0	0	0	0	TR								0	0	0	0
90/08/05	121	H	1400		OW	0	0	0	0	0								0	0	0	0
90/08/05	123	H	1500		9	0	0	0	0	9			1	3	0	30	60	0	0	150	250
90/08/05	124	H	1700		9	0	0	0	1	8			2	3	0	25	70	30	80	150	200
90/08/05	125	H	1800		9	0	0	0	1	8			2	3	0	20	75	30	80	150	300
90/08/05	126	H	1900		9	0	0	0	1	8			2	3	0	15	50	30	80	150	250
90/08/05	127	H	2000		9	0	0	0	0	9			2	3	0	15	80	0	0	130	200
90/08/05	130	H	2100	Y	9	0	0	0	1	8			2	3	0	15	70	50	120	150	400
90/08/05	131	H	2200	Y	9	0	0	0	0	9			2	3	0	20	30	0	0	150	500
90/08/05	132	H	2300		9	0	0	0	1	8			2	3	0	5	10	100	150	150	350
90/08/06	133	H	0000	Y	9	0	0	0	0	9			2	3	0	20	5	0	0	100	350
90/08/06	134	H	0100		9	0	0	0	0	9			2	3	0	20	5	0	0	100	350
90/08/06	135	H	0200		9	0	0	0	0	9			2	3	0	20	5	0	0	100	400
90/08/06	136	H	0300	Y	9	0	0	0	0	9			2	3	0	15	40	0	0	150	350
90/08/06	137	H	0400	Y	9	0	0	0	1	8			2	3	1	10	10	70	90	150	350

Table B.2 Predominant Ice Conditions Over Past Hour

Date	Event No.	Event Type	Time	Reference Log Entry	Sea Ice Concentrations (Tenths)						Predominant Floe Size				Thaw Holes	Melt Ponds	First-Year Rubble	Ice Thickness Estimates			
(yy/mm/dd)			(GMT)		Total	New	Grey	Grey-White	First -Year	Old	First-Year Min.	First-Year Max.	Old Min.	Old Max.	(%)	(%)	(%)	First-Year Min. (cm)	First-Year Max. (cm)	Old Min. (cm)	Old Max. (cm)
90/08/06	139	H	0500	Y	9	0	0	0	0	9			2	3	0	15	15	0	0	200	350
90/08/06	140	H	0600		9	0	0	0	0	9			2	3	0	15	15	0	0	200	350
90/08/06	142	H	0700	Y	9	0	0	0	0	9			2	3	0	20	15	0	0	250	350
90/08/06	144	H	0800		9	0	0	0	0	9			2	3	0	25	10	0	0	20	30
90/08/06	145	H	0900	Y	9	0	0	0	0	9			2	4	0	20	20	0	0	170	300
90/08/06	146	H	1000		9	0	0	0	0	9			2	4	0	20	20	0	0	170	400
90/08/06	147	H	1100		9+	0	0	0	0	9+			2	4	0	20	15	0	0	170	500
90/08/06	148	H	1200		9+	0	0	0	0	9+			2	4	0	20	10	0	0	170	400
90/08/06	150	H	1600		9	0	0	0	0	9			2	3	0	20	20	0	0	130	300
90/08/06	151	H	1700		9	0	0	0	0	9			2	2	0	20	20	0	0	150	350
90/08/06	152	H	1800		9	0	0	0	0	9			3	3	0	20	30	0	0	200	400
90/08/06	153	H	1900	Y	9	0	0	0	0	9			3	4	0	20	10	0	0	180	250
90/08/06	154	H	2000		9	0	0	0	TR	9			3	4	0	15	15	0	0	150	250
90/08/06	155	H	2100		9	0	0	0	0	9			2	4	0	15	15	0	0	150	250
90/08/06	156	H	2200		9	0	0	0	0	9			2	4	0	20	10	0	0	150	300
90/08/07	157	H	0000	Y	9	0	0	0	0	9			2	3	0	20	5	0	0	150	300
90/08/07	158	H	0100		9	0	0	0	0	9			2	3	0	20	5	0	0	150	300
90/08/07	159	H	0200		9	0	0	0	0	9			2	3	0	20	5	0	0	150	300
90/08/07	161	H	0300		9	0	0	0	0	9			2	3	0	20	5	0	0	150	350
90/08/07	162	H	0400		9	0	0	0	0	9			3	4	0	20	10	0	0	150	300
90/08/07	163	H	0500		9	0	0	0	0	9			2	4	0	25	5	0	0	200	300
90/08/07	164	H	0600		9	0	0	0	0	9			3	4	0	20	5	0	0	200	350
90/08/07	166	H	0900		9+	0	0	0	0	9+			3	4	0	20	5	0	0	200	400
90/08/07	167	H	1000	Y	9+	0	0	0	0	9+			3	4	0	15	5	0	0	200	400
90/08/07	168	H	1100		9+	0	0	0	0	9+			3	4	0	15	5	0	0	150	400
90/08/07	169	H	1200	Y	9+	0	0	0	0	9+			2	4	0	15	10	0	0	150	500
90/08/07	170	H	1300		9	0	0	0	0	9			2	4	0	15	5	0	0	150	400
90/08/07	171	H	1400		9	0	0	0	0	9			2	4	0	15	10	0	0	150	400
90/08/07	172	H	1500	Y	9	0	0	0	0	9			2	4	0	25	5	0	0	170	300
90/08/07	174	H	1700		9	0	0	0	0	9			2	4	0	30	5	0	0	150	250
90/08/07	175	H	1800		9	0	0	0	0	9			1	3	0	20	10	0	0	150	250
90/08/07	176	H	1900		9	0	0	0	0	9			2	4	0	20	10	0	0	150	250
90/08/07	177	H	2000		9	0	0	0	0	9			2	3	0	15	10	0	0	150	250
90/08/07	178	H	2100	Y	9+	0	0	0	0	9+			2	3	0	20	5	0	0	150	300
90/08/07	179	H	2200		10	0	0	0	0	10			3	4	0	5	5	0	0	200	300
90/08/07	180	H	2300		10	0	0	0	0	10			3	4	0	10	10	0	0	200	350
90/08/08	181	H	0000		9+	0	0	0	0	9+			3	3	0	10	20	0	0	200	350
90/08/08	182	H	0200	Y	9	0	0	0	0	9			3	3	0	25	25	0	0	200	300
90/08/08	183	H	0300	Y	9	0	0	0	0	9			3	4	0	20	25	0	0	150	300
90/08/08	184	H	0400		9	0	0	0	0	9			2	3	0	15	25	0	0	150	300

Table B.2. Predominant Ice Conditions Over Past Hour

Date	Event No.	Event Type	Time	Reference Log Entry	Sea Ice Concentrations (Tenths)						Predominant Floe Size				Thaw Holes	Melt Ponds	First-Year Rubble	Ice Thickness Estimates			
					Total	New	Grey	Grey-White	First -Year	Old	First-Year Min.	First-Year Max.	Old Min.	Old Max.				First-Year Min. (cm)	First-Year Max. (cm)	Old Min. (cm)	Old Max. (cm)
(yy/mm/dd)			(GMT)												(%)	(%)	(%)				
90/08/08	185	M	0600		9	0	0	0	0	9			2	3	0	20	15	0	0	150	250
90/08/08	186	M	0700		9	0	0	0	0	9			2	4	0	20	20	0	0	130	250
90/08/08	187	M	0800		9	0	0	0	0	9			2	3	0	15	15	0	0	150	350
90/08/08	188	M	0900	Y	9	0	0	0	0	9			2	4	0	10	30	0	0	150	300
90/08/08	191	M	2200		9	0	0	0	0	9			2	4	0	15	20	0	0	200	400
90/08/08	192	M	2300	Y	9	0	0	0	0	9			2	4	0	20	20	0	0	200	400
90/08/09	193	M	0000		9	0	0	0	0	9			2	4	0	15	20	0	0	200	400
90/08/09	194	M	0100	Y	9	0	0	0	0	9			2	4	0	15	10	0	0	200	400
90/08/09	195	M	0200		9	0	0	0	0	9			1	4	0	20	10	0	0	200	400
90/08/09	196	M	0300	Y	9	0	0	0	0	9			2	4	0	20	15	0	0	200	400
90/08/09	197	M	0400		9	0	0	0	0	9			3	4	0	20	10	0	0	200	400
90/08/09	198	M	0500		9	0	0	0	0	9			3	4	0		10	0	0	200	400
90/08/09	199	M	0600	Y	9	0	0	0	0	9			3	4	0	20	5	0	0	200	400
90/08/09	200	M	0700		9	0	0	0	0	9			3	4	0	20	15	0	0	200	400
90/08/09	202	M	0800		9	0	0	0	0	9			2	4	0	10	20	0	0	200	400
90/08/09	203	M	0900		9	0	0	0	0	9			3	4	0	10	20	0	0	200	400
90/08/09	204	M	1000		9	0	0	0	0	9			3	4	0	15	20	0	0	200	400
90/08/09	205	M	1100		9	0	0	0	0	9			3	4	0	25	20	0	0	200	400
90/08/09	206	M	1200		9	0	0	0	0	9			3	4	0	15	10	0	0	200	400
90/08/09	207	M	1300	Y	9	0	0	0	0	9			3	4	0	30	10	0	0	200	400
90/08/09	208	M	1400		9	0	0	0	0	9			3	4	0	25	30	0	0	200	400
90/08/09	209	M	1500	Y	9	0	0	0	0	9			3	4	0	30	20	0	0	150	350
90/08/09	210	M	1700		9	0	0	0	0	9			3	4	0	20	20	0	0	250	450
90/08/09	212	M	1800		9	0	0	0	0	9			3	4	0	25	15	0	0	200	350
90/08/09	213	M	2000		9	0	0	0	0	9			3	4	0	15	20	0	0	150	300
90/08/09	214	M	2100	Y	9	0	0	0	0	9			3	4	0	25	20	0	0	200	450
90/08/09	215	M	2200		9	0	0	0	0	9			3	4	0	10	25	0	0	200	450
90/08/09	216	M	2300	Y	9	0	0	0	0	9			3	4	0	20	10	0	0	150	350
90/08/10	217	M	0000		8	0	0	0	0	8			2	4	0	30	20	0	0	150	400
90/08/10	218	M	0100		9	0	0	0	0	9			2	4	0	30	5	0	0	150	400
90/08/10	219	M	0200		8	0	0	0	0	8			2	4	0	10	20	0	0	150	350
90/08/10	220	M	0300	Y	8	0	0	0	0	8			2	4	0	15	5	0	0	180	300
90/08/10	221	M	0400		9	0	0	0	0	9			2	4	0	25	5	0	0	150	300
90/08/10	222	M	0500		9	0	0	0	0	9			2	3	0	25	10	0	0	200	350
90/08/10	223	M	0600		8	0	0	0	0	8			2	3	0	20	5	0	0	200	350
90/08/10	224	M	0700		8	0	0	0	0	8			2	3	0	10	5	0	0	200	350
90/08/10	225	M	0800		8	0	0	0	0	8			1	4	0	10	10	0	0	200	350
90/08/10	227	M	0900		9	0	0	0	0	9			2	4	0	15	30	0	0	150	400
90/08/10	228	M	1000		8	0	0	0	0	8			2	4	0	30	20	0	0	150	400
90/08/10	229	M	1100		9	0	0	0	0	9			2	4	0	30	20	0	0	150	300

Table B.2 Predominant Ice Conditions Over Past Hour

Date	Event No.	Event Type	Time	Reference Log Entry	Sea Ice Concentrations (Tenths)						Predominant Floe Size				Thaw Holes	Melt Ponds	First-Year Rubble	Ice Thickness Estimates			
					Total	New	Grey	Grey-White	First-Year	Old	First-Year		Old					First-Year		Old	
(yy/mm/dd)			(GMT)								Min.	Max.	Min.	Max.	(%)	(%)	(%)	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)
90/08/10	230	H	1200		9	0	0	0	0	9			2	3	0	20	10	0	0	150	300
90/08/10	231	H	1300		9	0	0	0	0	9			2	3	0	20	10	0	0	150	400
90/08/10	232	H	1400		8	0	0	0	0	8			2	3	0	15	5	0	0	120	300
90/08/10	233	H	1500		9	0	0	0	0	9			3	3	0	15	10	0	0	130	300
90/08/10	234	H	1600		9	0	0	0	0	9			3	4	0	15	20	0	0	110	250
90/08/10	235	H	1700		9	0	0	0	0	9			2	3	0	10	10	0	0	110	250
90/08/10	237	H	1800	Y	9	0	0	0	6	9			1	3	0	5	25	0	0	90	250
90/08/10	238	H	1900		8	0	0	0	0	8			1	3	0	5	25	0	0	90	230
90/08/10	239	H	2000		8	0	0	0	0	8			1	2	0	15	15	0	0	90	200
90/08/10	240	H	2100	Y	9+	0	0	0	5	5	1	3	1	2	5	25	0	80	120	0	0
90/08/10	241	H	2200		9	0	0	0	2	7	1	2	5	5	5	25	30	80	200	80	200
90/08/10	242	H	2300		4	0	0	0	2	2	1	2	1	2			10				
90/08/11	244	H	0000		7	0	0	0	1	6	2	3	2	3	5	25	10			80	200
90/08/11	245	H	0100		9	0	0	0	3	6	2	4	2	4	10	30	15			80	200
90/08/11	246	H	0200		9	0	0	0	3	6	2	4	2	4	10	30	0			80	180

Table B.3 Hourly Performance Particulars

Date	Event No.	Event Type	Time	Reference Log Entry	Course Made Good	Distance Made Good	Transit Mode				Ship Speed	Measured Ice Thickness	Nuclear Reactor Power	Power Control					
							Open	Push	Break	Ram				Left Screw		Centre Screw		Right Screw	
														Power Level	Speed (rpm)	Power Level	Speed (rpm)	Power Level	Speed (rpm)
(yy/mm/dd)			(GMT)			(n.mi.)	(%)	(%)	(%)	(%)	(knots)	(cm)	(%)						
90/08/02	1	R	0500	Y			90	0	0	0	19		55	20	150	18	130	20	135
90/08/02	2	R	0650	Y	306	19	90	0	0	0	14		55	20	150	18	130	20	135
90/08/02	4	R	0700	Y	256	11	0	0	0	0			55	20	150	18	130	20	135
90/08/02	6	R	0800		267	19	90	10	0	0	20		55	20	150	18	130	20	135
90/08/02	7	R	0900		211	17	90	0	0	0	20		55	20	150	18	135	20	135
90/08/02	9	R	1000		207	20	90	0	0	0	19		55	20	150	12	150	20	135
90/08/02	11	R	1100		213	17	90	10	0	0	19		55	20	150	13	120	20	135
90/08/02	12	R	1200		218	19	90	10	0	0	19		55	20	150	20	130	20	130
90/08/02	13	R	1300		205	17	95	5	0	0	19		55	20	150	15	130	20	130
90/08/02	14	R	1400		217	25	90	0	0	0	20		55	20	150	15	135	20	130
90/08/02	15	R	1500		219	15	90	0	0	0	19		55	20	150	15	140	20	140
90/08/02	16	R	1600		219	17	90	0	0	0	19		55	20	150	15	130	20	135
90/08/02	17	R	1700		213	20	90	0	0	0	20		55	20	150	15	130	20	135
90/08/02	19	R	1800		235	17	95	5	0	0	20		55	20	150	15	130	20	135
90/08/02	22	R	1900		276	16	95	5	0	0	19		55	20	150	15	130	20	130
90/08/02	26	R	2000		291	14	80	20	0	0	16		55	10	100	14	120	7	75
90/08/02	27	R	2100		268	14	95	5	0	0	18		55	20	150	15	130	20	130
90/08/03	35	R	0300				99	0	0	0	18		55	20	150	15	130	20	130
90/08/03	38	R	0400		295	7	60	40	0	0	13		55	6	60	10	70	6	50
90/08/03	40	R	0500		333	9	90	10	0	0	11		55	9	70	10	70	12	80
90/08/03	44	R	0600	Y	316	11	10	50	60	0	8		55	9	50	12	60	8	55
90/08/03	48	R	0700		324	10	90	0	0	0	0		55	0	0	0	0	0	0
90/08/03	49	R	0800	Y	330	9	90	0	0	0	19		55	20	150	13	120	20	135
90/08/03	50	R	0900		293	16	90	0	0	0	19		55	9	80	14	110	9	85
90/08/03	52	R	1000		203	8	90	0	0	0	6		55	8	50	10	70	9	65
90/08/03	54	R	1100		316	16	90	0	0	0	19		55	20	150	14	150	20	130
90/08/03	55	R	1200		300	16	95	5	0	0	16		55	20	140	20	140	20	140
90/08/03	57	R	1300	Y	302	9	90	10	0	0	16		55	20	150	16	130	20	130
90/08/03	58	R	1400	Y	296	16	50	50	0	0	5		55	20	150	16	130	20	130
90/08/03	60	R	1500	Y	329	16	80	10	10	0	10		55	20	150	13	100	12	90
90/08/03	62	R	1700	Y			60	4	80	0	16		55	20	140	20	150	20	140
90/08/03	65	R	1800		265	11	0	90	0	0	15		55	20	140	20	135	20	145
90/08/03	68	R	1900		300	17	70	20	10	0	15		55	20	140	20	135	20	145
90/08/03	70	R	2000		302	6	30	30	0	40	15		55	20	140	20	140	20	130
90/08/03	72	R	2100	Y	300	10	0	25	80	0	17		55	20	140	18	120	20	130
90/08/03	73	R	2200	Y	297	10	0	50	50	0	16		55	20	140	20	130	20	130
90/08/03	75	R	2300	Y	297	15	90	0	0	0	16		55	20	150	17	130	20	130
90/08/04	77	R	0035	Y	8	0	90	0	0	0	16		55	20	150	17	130	20	130
90/08/04	78	R	0100	Y			50	0	50	0	17		55	20	150	17	130	20	130
90/08/04	79	R	0200	Y	314	13	50	0	50	0	17		55	20	150	17	130	20	130
90/08/04	81	R	0300		327	16	80	0	20	0	16		55	20	145	17	130	20	130
90/08/04	83	R	0400		326	16	30	50	20	0	17		55	20	140	20	130	20	130
90/08/04	86	R	0500		316	10	0	90	0	0	15		55	20	130	20	130	20	140
90/08/04	88	R	0600		318	12	50	50	0	0	18		55	20	140	13	120	20	130
90/08/04	89	R	0700		318	17	20	80	0	0	17		55	20	0	14	120	20	130
90/08/04	90	R	1100				90	0	0	0	8		55	20	0	14	120	20	130
90/08/04	91	R	1200	Y	326	16	0	5	95	0	12		55	20	0	14	130	20	130
90/08/04	93	R	1300	Y	17	16	80	10	0	0	18		55	20	0	14	130	20	130
90/08/04	94	R	1400	Y	342	16	50	5	45	0	17		70	20	0	20	130	20	140
90/08/04	95	R	1500		337	16	10	20	70	0	17		70	20	0	20	140	20	130

Table B.3 Hourly Performance Particulars

Date	Event No.	Event Type	Time	Reference Log Entry	Course Made Good	Distance Made Good	Transit Mode Open	Transit Mode Push	Transit Mode Break	Transit Mode Ram	Ship Speed	Measured Ice Thickness	Nuclear Reactor Power	Power Control Left Screw Floor Level	Power Control Left Screw Speed	Power Control Centre Screw Floor Level	Power Control Centre Screw Speed	Power Control Right Screw Floor Level	Power Control Right Screw Speed
(yy/mm/dd)			(GMT)			(n.mi.)	(%)	(%)	(%)	(%)	(knots)	(cm)	(%)		(rpm)		(rpm)		(rpm)
90/08/04	98	O	1700	Y			0	10	85	0	8		70	20	0	20	100	70	100
90/08/04	98	O	1800		2	10	0	10	85	0	10		70	20	0	20	100	20	100
90/08/04	99	O	1900		30	12	20	0	80	0	9		70	20	0	20	100	20	140
90/08/04	101	O	2000		40	9	0	10	80	0	10		70	20	0	20	100	20	100
90/08/04	102	O	2100	Y	100	12	0	0	95	0	10	170	70	20	0	20	100	20	150
90/08/04	103	O	2200	Y	60	14	0	0	99	0	15	100	70	20	0	20	100	20	150
90/08/04	104	O	2300		69	14	0	0	99	0	14	120	70	20	0	20	100	20	150
90/08/05	105	O	0000		60	11	0	0	99	0	11	100	70	20	0	20	100	20	150
90/08/05	106	O	0100		61	10	0	0	99	0	10	100	80	13	0	13	100	13	150
90/08/05	107	O	0200		60	10	0	0	99	0	8	140	80	20	0	20	100	20	150
90/08/05	108	O	0300		70	10	0	0	90	0	16		80	12	0	11	110	12	100
90/08/05	109	O	0400		69	12	0	0	95	0	15		80	10	0	10	100	12	140
90/08/05	110	O	0500	Y	30	10	80	0	10	0	18		80	15	0	15	100	15	140
90/08/05	114	O	1000		10		10	0	80	0	16	160	80	20	150	20	100	20	140
90/08/05	117	O	1100		240	12	0	0	95	0	16	180	80	20	100	20	100	20	140
90/08/05	120	O	1300	Y			90	0	0	0	17		80	10	100	10	110	16	100
90/08/05	121	O	1400		20	16	99	0	0	0	16		80	10	100	10	110	17	140
90/08/05	123	O	1500		50	14	50	20	20	0	10	170	80	20	140	20	140	20	150
90/08/05	124	O	1700				0	10	80	0	13	150	80	20	100	10	140	20	140
90/08/05	125	O	1800		300	16	0	10	80	0	14	200	80	20	140	20	140	20	150
90/08/05	126	O	1900		300	12	0	10	80	0	13		90	20	180	20	100	20	150
90/08/05	127	O	2000		337	12	0	5	80	0	10	170	90	20	140	20	140	20	140
90/08/05	130	O	2100	Y	300	10	0	0	[illegible]	60	6	180	90	20	140	20	140	20	140
90/08/05	131	H	2200	Y	357	7	0	0	80	20	14	140	90	20	140	20	145	20	140
90/08/05	132	H	2300		9	8	5	0	90	5	3	110	90	20	110	20	130	20	130
90/08/06	133	H	0000	Y	348	10	0	0	99	0	13	185	90	20	110	20	130	20	130
90/08/06	134	H	0100		332	11	10	0	90	0	15	240	90	20	110	20	130	20	130
90/08/06	135	H	0200		325	11	0	0	99	0	10	140	90	20	150	20	140	20	140
90/08/06	136	H	0300	Y	320	9	0	5	95	0	10	140	95	20	150	20	150	20	150
90/08/06	137	H	0400	Y	359	7	0	5	95	0	14	160	95	20	150	20	150	20	150
90/08/06	139	H	0500	Y	334	9	5	5	75	15	14	125	90	20	130	20	130	20	130
90/08/06	140	H	0600		330	10	0	5	95	0	12		90	20	130	20	150	20	150
90/08/06	142	H	0700	Y	316	10	0	5	95	0	9	200	100	20	130	20	130	20	130
90/08/06	144	H	0800		11	7	0	10	90	0	11		100	20	150	20	150	20	140
90/08/06	145	H	0900	Y	28	9	0	0	99	0	13	175	100	20	140	20	150	20	140
90/08/06	146	H	1000		32	11	0	0	90	10	14	230	100	13	130	12	120	13	130
90/08/06	147	H	1100		30	5	0	0	80	20	12	185	100	13	130	12	120	13	130
90/08/06	148	H	1200		51	6	0	0	85	15			100	13	130	12	120	13	130
90/08/06	150	H	1600				0	5	95	0	14	225	100	12	140	16	140	12	140
90/08/06	151	H	1700		102	10	0	5	95	0	7		100	20	150	20	150	20	150
90/08/06	152	H	1800		33	13	0	0	99	0	14	170	100	20	120	20	140	20	150
90/08/06	153	H	1900	Y	16	8	0	0	99	0	10		100	20	140	20	140	20	140
90/08/06	154	H	2000		2	8	0	0	99	0	11		100	20	140	20	140	20	120
90/08/06	155	H	2100		352	12	0	0	99	0	12	165	100	20	150	20	150	20	160
90/08/06	156	H	2200		18	9	0	0	99	0	13	180	100	20	150	20	150	20	160
90/08/07	157	H	0000	Y			10	0	90	0	8	175	100	20	150	20	150	20	160
90/08/07	158	H	0100		327	12	0	0	99	0	14	235	100	20	150	20	150	20	160
90/08/07	159	H	0200		350	10	0	0	99	0	14	230	100	20	150	20	150	20	160
90/08/07	161	H	0300		346	9	0	0	99	0	10		100	20	150	20	130	20	150
90/08/07	162	H	0400		23	11	0	0	99	0	7		100	20	130	20	140	20	140

Table B.3 Hourly Performance Particulars

Date	Event No.	Event Type	Time	Reference Log Entry	Course Made Good	Distance Made Good	Transit Mode				Ship Speed	Measured Ice Thickness	Nuclear Reactor Power	Power Control					
							Open	Push	Break	Ram				Left Screw		Centre Screw		Right Screw	
(yy/mm/dd)			(GMT)			(n.mi.	(%)	(%)	(%)	(%)	(knots)	(cm)	(%)	Power Level	Speed (rpm)	Power Level	Speed (rpm)	Power Level	Speed (rpm)
90/08/07	163	H	0500		349	8	5	5	90	0	15		100	20	130	20	150	10	130
90/08/07	164	H	0600		34	10	0	0	99	0	11		100	20	140	20	150	20	150
90/08/07	166	H	0900				0	0	99	0	13	275	100	20	150	20	150	20	150
90/08/07	167	H	1000	Y	334	10	0	0	99	0	11	175	100	20	150	20	150	20	150
90/08/07	168	H	1100		353	5	0	0	90	10	12	160	100	20	150	20	150	20	150
90/08/07	169	H	1200	Y	1	9	10	0	60	30	3	215	100	20	150	20	150	20	150
90/08/07	170	H	1300		353	8	10	0	90	0	12	175	100	20	150	20	150	20	150
90/08/07	171	H	1400		341	10	10	0	90	0	10	200	100	20	150	20	150	20	150
90/08/07	172	H	1500	Y	339	11	0	0	99	0	13		100	20	130	20	140	20	110
90/08/07	174	H	1700				0	0	99	0	2		100	20	130	20	130	20	130
90/08/07	175	H	1800		25	9	0	0	99	0	11		100	20	150	20	150	20	150
90/08/07	176	H	1900		7	7	0	0	85	15	5		100	20	150	20	150	20	150
90/08/07	177	H	2000		359	11	0	0	99	0	10		100	20	150	20	150	20	150
90/08/07	178	H	2100	Y	12	8	0	0	80	20	5	180	100	20	150	20	150	20	150
90/08/07	179	H	2200		4	5	0	0	70	30	10	300	100	20	150	20	150	20	150
90/08/07	180	H	2300		344	4	0	0	90	10	10	165	100	20	150	20	150	20	150
90/08/08	181	H	0000		319	8	0	0	90	10	11	205	100	20	150	20	150	20	150
90/08/08	182	H	0200	Y			0	0	80	20	3	230	100	20	150	20	150	20	150
90/08/08	183	H	0300	Y	327	7	0	0	90	10	9		100	20	150	20	150	20	150
90/08/08	184	H	0400		322	10	0	0	99	0	13		100	20	150	20	150	20	150
90/08/08	185	H	0600				0	0	99	0	11		100	20	150	20	150	20	150
90/08/08	186	H	0700		16	12	0	0	99	0	14	175	100	20	150	20	150	20	150
90/08/08	187	H	0800		75	31	0	0	99	0	11	175	100	20	150	20	150	20	150
90/08/08	188	H	0900	Y	75	31	0	0	99	0	2		100	20	150	20	150	20	150
90/08/08	191	H	2200				0	0	99	0	9	205	100	20	150	20	150	20	150
90/08/08	192	H	2300	Y	0	0	5	0	95	0	13	175	100	20	150	20	150	20	150
90/08/09	193	H	0000		0	0	0	0	99	0	4	180	100	20	150	20	150	20	150
90/08/09	194	H	0100	Y	104	8	0	80	20	0	14	185	100	20	150	20	150	20	150
90/08/09	195	H	0200		107	9	0	99	0	0	15	200	100	20	150	20	150	20	150
90/08/09	196	H	0300	Y	178	11	0	99	0	0	15		100	20	150	20	150	20	150
90/08/09	197	H	0400		137	11	0	99	0	0	8		100	20	100	20	150	20	160
90/08/09	198	H	0500		169	9	0	95	5	0	12		90	20	130	20	130	20	150
90/08/09	199	H	0600	Y	176	8	0	95	5	0	13		100	20	130	20	150	20	150
90/08/09	200	H	0700		138	11	0	90	10	0	14		90	20	130	20	140	20	150
90/08/09	202	H	0800		176	12	0	95	5	0	13		90	20	160	20	160	20	160
90/08/09	203	H	0900		163	13	0	50	50	0	10	200	90	20	160	20	160	20	160
90/08/09	204	H	1000		179	9	5	40	55	0	6	250	90	20	140	20	150	20	150
90/08/09	205	H	1100		158	6	5	30	65	5	14	200	100	20	140	20	150	20	150
90/08/09	206	H	1200		169	8	5	5	90	0	9	205	100	20	140	20	150	20	150
90/08/09	207	H	1300	Y	153	9	10	0	90	0	12	180	100	20	140	20	150	20	150
90/08/09	208	H	1400		142	13	10	0	90	0	10	210	100	20	140	20	150	20	150
90/08/09	209	H	1500	Y	144	7	0	10	90	0	15	170	100	20	100	20	150	20	160
90/08/09	210	H	1700				10	5	85	0	9	230	100	20	100	20	150	20	160
90/08/09	212	H	1800		156	9	5	5	90	0	11	190	100	20	70	20	140	20	140
90/08/09	213	H	2000				10	5	85	0	13	170	100	20	100	20	140	20	150
90/08/09	214	H	2100	Y	126	12	10	0	90	0	12	210	100	20	100	20	140	20	150
90/08/09	215	H	2200		159	14	15	5	80	0	13	215	100	20	100	20	140	20	150
90/08/09	216	H	2300	Y	157	13	30	0	70	0	16	160	100	20	100	20	140	20	150
90/08/10	217	H	0000		130	16	40	0	60	0	15	150	100	20	100	20	140	20	150
90/08/10	218	H	0100		134	8	35	0	65	0	12	340	100	20	100	20	140	20	150

Table B.3 Hourly Performance Particulars

Date	Event No.	Event Type	Time	Reference Log Entry	Course Made Good	Distance Made Good	Transit Mode				Ship Speed	Measured Ice Thickness	Nuclear Reactor Power	Power Control					
							Open	Push	Break	Ram				Left Screw		Centre Screw		Right Screw	
														Power Level	Speed (rpm)	Power Level	Speed (rpm)	Power Level	Speed (rpm)
(yy/mm/dd)			(GMT)			(n.mi.	(%)	(%)	(%)	(%)	(knots)	(cm)	(%)						
90/08/10	219	H	0200		141	13	40	60	0	0	20		90	16	130	11	130	12	150
90/08/10	220	H	0300	T	134	14	30	10	30	0	10		90	20	140	20	140	20	130
90/08/10	221	H	0400		139	11	40	0	60	0	10		90	20	150	14	130	20	160
90/08/10	222	H	0500		165	11	10	10	80	0	13	180	90	20	150	20	150	20	150
90/08/10	223	H	0600		181	13	30	10	60	0	13		90	20	150	20	160	20	150
90/08/10	224	H	0700		175	14	25	5	70	0	9	250	90	20	150	15	140	20	160
90/08/10	225	H	0800		207	8	70	5	25	0	11		90	12	140	13	140	13	150
90/08/10	226	H	0900		206	14	60	0	40	0	15	165	90	20	150	20	150	20	150
90/08/10	228	H	1000		169	17	60	0	40	0	13	135	90	8	120	8	90	9	130
90/08/10	229	H	1100		190	9	70	5	25	0	16	140	90	8	120	8	90	9	130
90/08/10	230	H	1200		185	8	30	5	65	0	14	180	90	10	120	11	120	11	130
90/08/10	231	H	1300		195	17	40	10	50	0	15	220	90	10	120	11	120	11	130
90/08/10	232	H	1400		216	7	40	10	50	0	13	120	90	10	120	11	120	11	130
90/08/10	233	H	1500		168	9	10	10	80	0	15		90	20	140	20	150	20	150
90/08/10	234	H	1600		175	13	10	0	90	0	16	250	90	20	140	20	150	22	150
90/08/10	235	H	1700		190	13	10	10	80	0	6		90	20	140	20	150	20	150
90/08/10	236	H	1800	T	182	13	20	5	75	0	11		90	20	140	20	150	20	150
90/08/10	238	H	1900		186	14	30	0	70	0	17	170	90	15	150	18	150	13	150
90/08/10	239	H	2000		181	16	30	0	70	0	18		90	18	160	16	150	12	160
90/08/10	240	H	2100	T	170	14	0	0	99	0	17		90	18	160	16	150	12	160
90/08/10	241	H	2200		173	13	0	30	70	0	16	115	90	20	160	20	150	20	160
90/08/10	242	H	2300		177	14	80	20	0	0	16		90	20	160	20	150	20	160
90/08/11	244	H	0000		183	17	40	0	60	0	11	145	70	20	160	20	150	20	160
90/08/11	245	H	0100		188	6	10	0	90	0	16	140	70	20	160	20	150	20	140
90/08/11	246	H	0200		184	19	10	0	90	0	17	135	70	20	160	20	150	20	140

Table B.4

Observation Log Reference Diary

Event No.	Date /Time	Description
1	02/0500	First ice encountered. Proceeding with one nuclear reactor on-line at 55% capacity, second reactor on stand-by.
2	02/0600	About one half of the first-year ice this hour has been recently rafted to twice its normal thickness, although it does not appear fully consolidated.
3	02/0640	Photograph 2/9 shows view along starboard side of 9/10, very decayed first-year 0.5 to 1.5m thick. Photographs 2/10,11 show typical thaw holes within melt ponds. Photograph 2/12 (at 0658z) shows track through first-year ice with rubble field beyond. Ship reversed for 3 minutes after slowing in the rubble, now altering course to go around.
4	02/0700	Photographs and video of ROSSIA breaking ice collected from helicopter between 0704 and 0720z.
8	02/0910	Ice forecast chart for 2-4 August photographed; shows total ice concentration only.
23	02/1920	Altering course $\pm 10^\circ$ continuously looking for lightest conditions. Ice thickness generally less than 1.5m, very decayed. Floe surfaces show evidence of extensive ridging and rubble formed at grey-white growth stage.
26	02/2046	Altering course to join escort convoy which is standing by 20 n.mi. away, north of Stones Island.
28	02/2114	Approaching convoy.
30	02/2145	Photographs of ships: 1) SOVETSKIY SOYUZ (red) - 75,000 HP nuclear icebreaker, sister ship to ROSSIA. 2) MURMANSK (yellow) - 35,000 HP diesel electric icebreaker. 3) M/V TOLJA KOMAR (white) - general cargo vessel. 4) TAYMYR (cream) - 50,000 HP shallow draft (8m) nuclear icebreaker is ahead.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
31	02/2155	Stop for about 2 hours to await arrival of Murmansk Shipping Company representatives joining vessel by helicopter from Dixon shore station.
32	03/0210	Preparing to resume voyage. Throughout the stop weather was foggy with light snow, and air temperature rose from -1 to +2 C.
33	03/0234	ROSSIA is underway, turing onto course.
34	03/0254	The convoy is underway with SOVETSKIY SOYUZ leading, followed by MURMANSK, M/V TOLJA KOMAR and TAYMYR. ROSSIA follows alongside, moving ahead and falling back for the benefit of passengers.
36	03/0331	Photos of navigation bridge (starboard side). Stopped by first officer from taking photographs in the area of the chart table.
37	03/0346	TAYMYR is departing the convoy; ROSSIA follows at 1/2-1 km behind.
39	03/00453	Convoy operating in close procession, ships are 100-200 apart. ROSSIA will continue following for next 1-2 hours, until all passengers have had an opportunity to view the procession from the air. ROSSIA will then break away and proceed northward.
41	03/0504	Photographs showing melt ponds and thaw holes.
42	03/0514	Behind the two lead icebreakers, the cargo vessel finds the track 80-90% ice free. Following in a gently weaving track, the escorted vessel stays about 1 ship length behind. Ship's hydrologist tells us that even in heavy ice conditions, the track is usually quite clear. Note that the beam of this cargo vessel appears about half that of lead icebreaker. Photos show mainly ice free track.
44	03/0600	ROSSIA now leading convoy at 9 knots.
46	03/0645	Radio officer delivers to ship hydrologist a series of 3 regional weather forecast charts of different scales and aerial coverage, as well as one weather satellite image (appears to be METEOR but cannot confirm) covering the area from 65-90^{0}N, 0-130^{0}E. Our present

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
		position is under cloud. All products received on wet paper radio facsimile from a regional weather office; good quality transmission is quite legible.
47	03/0655	Vessel stopped for 30 minutes, apparently to align ship for INMARSAT communications.
49	03/0800	ROSSIA now catching up to rejoin convoy.
51	03/0920	Moving slowly with convoy, first ice reconnaissance flight is underway, helicopter is expected to be away up to 4 hours.
56	03/1245	Stopped for about 10 minutes to visually survey ice conditions and select a route. After sailing through very open pack for last several hours, open conditions have narrowed with close pack ice on port side meeting shorefast ice on starboard side.
57	03/1300	Leads ranging from 0.5 to 2km wide run ahead between the shorefast and pack ice, with a few smaller floes of less than 50m diameter. In places the ice pinches off for distances of 100 to 300m.
58	03/1400	Slowed down to proceed through a pinch point. On starboard side ice is 10/10 shorefast, and on port side 8/10 pack ice. Continue following leads between these regimes as much as possible, so that although ice conditions along the vessel path averaged 7/10 over last hour, transit mode data show 50% of time in open water.
	03/1403	Back up to speed.
59	03/1405	Photographs taken of observed charts from recent helicopter reconnaissance flights. Charts #1,2,3,4 from August 1 and 2 are at 1:500k scale, with the observed swath about 2 n.mi.
60	03/1500	Air bubbling system is turned on for first time. (Note: remains operational for duration of ice transit).
61	03/1645	Helicopter departs on 15 minute reconnaissance, ice observer reports back directly to Captain.
62	03/1700	No significant ridges have been encountered recently; all have been $\leq$ 1m in sail height. Nilas ice covers most melt ponds now.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
63	03/1740	Photographs of track; centre is clear, with ice cake size pieces (mostly < 3m diameter) found along both sides. Extensive fracturing into the surrounding ice increases the track width by about 50% with small floes.
64	03/1745	Begin following an existing broken track filled mainly with brash ice, some ice cakes. Track has refrozen, although not extensively.
67	03/1830	Drifting ice has widened track and port side is now all open water and nilas ice.
69	03/1903 03/1924	Polar bears alongside - reverse engines and call to tourists. Resume voyage.
71	03/2030	Continue moving in existing ship track, now with fast ice on either side. Track has much less ice concentration astern of ROSSIA.
72	03/2100	Passing through Matissen Strait north of Taymyr Island, still following the existing ship channel through level fast ice which is partly of second-year ice. Occasionally a ship track from the 1989 season can be seen. Passed by the Poluostrov meteorological station on Pravda Island.
73	03/2200	Four polar bears in area.
74	03/2225	Entering gradually widening open water lead between shorefast ice zones of the mainland and the islands.
75	03/2300	Following a lead 300m wide through fast ice. Concentration in the lead is about 1/10.
76	03/2320	Photographs of multi-year floes (~70, 100 and 200m diameters) embedded in the fast ice, with ridging around the edges.
77	04/0035	Following a lead 500m to 2km wide through the fast ice.
78	04/0100	Following leads 30-500m wide through fast ice and occasionally through small floe pack ice. Frequent heading changes.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
79	04/0200	Lead through fast ice varies from 50 to 500m wide. Several ridges of around 2m sail height have been encountered over last hour - about 1 ridge/km.
80	04/0235	On manual wheel, continuous course alternations to follow lead. Heading calls from Captain and OOW are rare, and wheelsman chooses path.
82	04/0332	End of lead pattern, entering previously broken track through fast first-year ice. Track is covered by unconsolidated brash and ice cake. Fractures through adjacent form smaller floes such that broken channel width about 60m, or twice the ROSSIA beam.
		Photograph shows at least 2 separate tracks which have diverged to leave larger floes between.
85	04/0510	Stop for Polar Bear watching.
	04/0521	Resume voyage.
87	04/0545	Meet and pass close by ARCTICA (formerly BREZHNEZ and before that, ARCTICA) approaching from the east, 75,000 HP nuclear icebreaker, first of the sister ships to ROSSIA, for which class was named.
91	04/1200	Manoeuvring to follow leads through floes 30-200m diameter. Port side tachometer has malfunctioned.
93	04/1300	Multi-year ridge remnants and second year ice floes.
94	04/1400	Following leads containing 1-2/10 mixed composition small floes amongst fields of first-year ice with numerous embedded second year and multi-year ice ridges and hummocks having sail heights up to 3-4m high.
		Ice concentration gradually increasing to between 4 and 8 tenths, with multi-year comprising 25-30% of the total. Several leads of 0.5 to 2km, between ice fields of 2 to 5km diameter.
	04/1439	Both reactors now on line, power rate increased to 70% as heavier ice expected ahead.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
96	04/1700	Mixed pack first-year and second year ice, everything from small to big floes (big floes earlier: small floes in video footage). Rubble becoming more extensive, comprised mainly of grey-white ice blocks. Occasionally reaches 2m sail height, but most is only about 1m in height.
100	04/1938	Photographs show ship track rounding second year ice rubble field with sail heights typically to 2.5m.
102	04/2100	Exploiting leads 10-100m wide. Changing course to west towards the Bolshevik Islands's northernmost tip, for sightseeing purposes.
103	04/2200	Passing by first-year and second year rubble fields, exploiting where possible leads which are mostly less than 50m wide, but generally running in direction of travel.
110	05/0413	Following lead between meandering edge of shorefast multi-year ice on port side, and pack ice to starboard. Lead width is variable but generally around 1 km wide, and favourably oriented northward.
111	05/0433	Still following ice edge, many icebergs are trapped in the fast ice to port.
112	05/0500	Lead width down now to 300-400m.
113	05/0515	Slowing alongside multi-year fast ice for passenger expeditions to Cosmonaut Island by helicopter.
114	05/0550	Vessel notches into landfast multi-year ice about 3m thick, stopping to allow passenger excursions.
115	05/0916	Resume voyage along shorefast ice lead containing small first-year and second year ice floes, and many growlers.
120	05/1300	Following lead 5-10m wide.
128	05/2010	Photograph shows consolidated ridge with approximately 3m sail in bottom of photo, other similar ridges beyond. Rubble classed as: 60% - consolidated 0-2m sail; 10% - consolidated 2-3m sail; 30% - fresh unconsolidated, 1-2m sail (mainly around floe edges).

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
130	05/2100	Difficulty experienced this past hour in breaking through field of heavily ridged multi-year ice 3-4m thick. 20 to 30 minutes spent in reverse/ram cycles, however impact speeds were generally only 3-4 knots and main purpose in reversing seemed to be to loosen friction to allow progress, not to "attack" the ice.
133	06/0000	Manoeuvring to follow leads and cracks.
136	06/0300	Photographs as follows: 5/23 view east from upper deck 5/24 view over side of breaking first-year ice 5/25 view back along track; first-year ice in photo 5/24 is about 200m behind vessel, now breaking old ice visible in foreground. 5/26-7 views over side of old ice breaking. Layering seems to indicate formation by rafting. This ice is probably second or third year as ridging is only moderately weathered, but still has high freeboard and interconnecting melt ponds indicative of old ice.
137	06/0400	Old ice thickness varies from 1.5 to 3.0 or 3.5m within a single small floe, as shown in photographs over the side. Again, layers can be seen in the greater thicknesses. A thin (10-20cm) crust of snow on surface. Melt pond coverage is gradually decreasing over past few hours, and they are less deep (maximum around 50cm?). No sign of any thaw holes has been seen lately.
138	06/0407	Light pressure building, ship reverses and rams. Photograph shows fresh ridging at pinched floes.
139	06/0500	Two reverse/ram cycles this past hour, one documented on video log.
142	06/0700	Heading north ±30-60°, continuous weaving on manual steering to follow path of smallest floes and most open water. Captain waves helmsman the general direction to steer, but does order course.
145	06/0900	Pressure building light to moderate over last 2 hours. Fresh ridging is forming around the perimeter of contacting ice floes.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
149	06/1201	Vessel stopped in honour of visit by King Neptune and friends, ensuing celebration.
	06/1500	Resume voyage.
153	06/1900	5-10cm of crusty snow cover.
157	07/0000	Moving in a lead 10-50m wide.
160	07/0240	Photograph 7/4 shows grey to grey-white ridging piled to over 2m sail height - this has been predominant ridging type over last few hours. Otherwise floes show little relief, only minor topography consisting mainly of unconsolidated rubble around floe edges as shown in photograph 7/5.
		On larger floes some melt ponds are quite extensive, up to 100m and more across and 50-75cm deep. On smaller floes ponds are relatively small (3-10m diameter), as evident in photographs.
165	07/0640	Helicopter has landed on the ice about 100m from ship and shut down, disabled. Ship has stopped to allow engineers to disembark.
	07/0830	Resume voyage.
167	07/1020	Vessel stopped on request of the helicopter engineers, who are in the process of installing a new engine.
	07/1040	Resume voyage.
169	07/1200	Pressure has eased off entirely, exploiting where possible 20-50m wide leads. Ridge sails are typically 2-2.5, with some peaks reaching 3-3.5m. Our estimate is that ice is mostly 3 years old.
		Extensive plankton can be seen around cracks and on the underside of turing ice pieces.
172	07/1500	Photograph 7/21 shows an ice sheet profile with old ice making up the top 100-120 cm, beneath which about 60 cm of first-year ice growth can be seen.
173	07/1630	Fog has lifted and rain diminished, however winds continue to blow strong at 30-35 knots and therefore helicopter cannot fly.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
		For some reason which is not apparent, vessel changes course to east, continues to swing around onto a southerly heading, and by 1645 a full circle has been completed and the north heading resumed.
178	07/2100	Moderate pressure forces ship to engage in back and forward motion to maintain progress through 2.5 to 3.5m thick ice floe. 4 "rams" required to make about 1-1/2 ships length.
182	08/0200	Winds are falling off and helicopter reconnaissance flights are resumed.
183	08/0300	A mix of fresh and older ridging, mostly 1-2m with some 3m sail heights. Leads between medium and big floes are being exploited, and along ships path many small floes have broken off where larger floes have come into contact.
188	08/0900	Arrival at North Pole after much of past hour was spent attempting to position vessel as closely as possible to the pole. Vessel has now stopped in a nearby medium sized multi-year floe.
	08/2130	Resume voyage now heading south.
191	08/2200	Completed a wide turn into the western hemisphere, and return to pass 300m from the North Pole, heading south.
192	08/2300	Ridges appear 2 or 3 years old, with sails of 2.5 to 3.5m. Leads and major cracks are now more open, with no evidence of pressure.
194	09/0100	Moved into our old channel this past hour, and continue along it.
196	09/0300	Track is completely covered in brash and ice cake. So far there has been little relative drift in ice floes.
199	09/0600	Track is beginning to close slightly in a few places, width is variable as shown in photographs. Vessel frequently bumps into sides of track to deflect course and assist turning, but only rarely (once in past hour) has it been necessary to break through a floe to cut a corner off the track.

Table B.4 (continued)

Observation Log Reference Diary

Event No.	Date /Time	Description
201	09/0738	Track ahead is closed up, with ridging an indication of earlier pressure. Ship slows as it commences icebreaking. Photograph shows fresh ridging parallel to old track.
	09/0743	Back in undeformed track.
203	09/0900	The old channel is increasingly deformed and discontinuous, sometimes compressed and meandering.
207	09/1300	Present location of track is approximately 10-12 n.mi. west of northbound route. There is no longer an attempt to keep to the old channel, however some parts have been encountered periodically. Continuous helicopter reconnaissance flight from 0900.
214	09/2100	Following a pattern of leads with open water and broken floes of 3-30m diameter. Many cracks in ice are probably an indication of recent pressure, however the leads now are opening.
216	09/2300	Leads are 20-300m wide, favourably oriented and sometimes as long as 1-1.5 n.mi.
220	10/0300	Grease ice and some dark nilas ice covers about 20% of the open water leads through which we are travelling.
236	10/1707	Vessel stops, unable to determine reason.
	10/1712	Resume voyage.
237	10/1800	Most rubble now has only 1-2m sail height. Old ice appears to have become exclusively second year with a first-year interface at a depth of approximately 50cm. Floes are weaker and fracture more easily than previously.
240	10/2100	Vast floe of level ice appears to have broken off a shorefast ice regime of the nearby Franz Joseph Islands.
247	11/0305	Entering open water, no ice in sight.

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Appendix C

VHS Video Log

Appendix C

VHS Video Log

Segment Number	Chronology Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Description Reference Log Event Number	Supplementary Comments

Note: Time annotation on video recording reads one hour ahead of GMT for first three segments.

1	90/08/02	0552	0	2	Ice conditions
2		0700	29	4	"
3		1200	301		"
4		1300	321		"
5		1700	334		"
6		1900	336		"
7		2000	356		"
8		2100	381		"
9		2120	400	28	"
10		2145	422	30	Approaching convoy from behind
11	90/08/03	0234	479	33	Broken channel
12		0254		34	Passing convoy
13		0400			SOVETSKIY SOYUZ
14		0708	607	49	Convoy in open pack
15		0920	795	51	Conversation with ship's hydrologist
16		1750	805	64	Following old broken channel
17		1800	844		Ice pieces in track are now unconsolidated and melting out. Some rounded ice pieces up to ice cake size

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
18		1900	872		Following old channel and leads along fast ice edge to starboard, 8/10 medium and big floe decayed first-year ice to port. Interesting pattern of straight, cris-crossed melt grooves in the fast ice, which is second year ice according to hydrologist.
19		2030	930	71	Decayed ice bends in ship's wake
20		2100	940	72	
21		2200	974	73	Broken channel here contains larger pieces up to 3m diameter. Polar bears in channel and alongside
22	90/08/04	0300	1048		Ice cusps have broken free from ice adjacent to broken channel, widening channel to almost 100m and filling it with pieces up to 10m diameter
23		0515	1078	85	Polar bear alongside
24		0545	1120	87	Meeting ARCTICA. Ice bends easily in ship's wake; meltponds appear to be about half drained of melt water; passengers on upper deck and navigation bridge
25		1116	1220		Ice conditions; small multi-year floes
26		1205	1226	91	Ice conditions
27		1309	1291	93	"

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
28		1657	1304	96	Continuous transit through second year ice; thaw holes
29		2030	1334		Melt ponds are smallish, about 2m wide but connected in elongated drainage patterns; pond edges cut under surrounding ice; about 10cm of a crusty snow cover is first well defined snow layer seen to date; much of the surface melt has drained, and some shallow melt ponds are snow covered
30		2108	1403	102	Ice conditions
31		2216	1445	103	"
32		2308	1471		"
33	90/08/05	0120	1486		Ice pieces in track; larger pieces along sides with open water strip in centre
34		0204	1514		Floes are predominantly level ice with rubble around edges
35		0308	1573		Ice conditions
36		0400	1602		"
37		0410	1615	110	Pushing ice cakes and small floes about 1m thick
38		0433	1650	111	Following open water lead about 1km wide; icebergs embedded in the fast ice to port, along the Severnaya Zemla Islands

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
39		0500	1677	112	Lead now 300-400m wide, up to 1/10 icebergs within fast ice zone; trace of multi-year ice cakes within the lead
40		0925	1726		Thaw holes becoming rare; deeper melt ponds with well developed drainage patterns; last 100m of floe fractures easily
41		1016	1758		Ice conditions
42		1106	1794		"
43		1124	1817		Ice condition; following lead about 1km wide; icebergs
44		1230	1829		Ice conditions
45		1446	1835		"
46		1753	1845		"
47		1830	1848		Fresh rubble around floe edges, but no multi-year hummocks and very few consolidated old ridges have been seen
48		1835	1878		Refrozen first-year ice lead covered 70% by melt
49		1845	1882		Breaking through multi-year ice about 2m thick; view of fairly large (2-3m diameter) ice pieces in track; views down port side of vessel and off stern; padded stern towing notch can be seen

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
50		1850	1935		Entering big multi-year floe with extensive, relatively young ridges; several views with camera held over bow rail looking down at cusping pattern (due to flare of hull it was not possible to observe this area visually)
51		2112	1972	130	Views over bow rail while moving slowly in heavy ice; wash resulting from air bubbler system
52		2203	2026		Ice conditions
53		2240	2041		Moving slowly through vast floe
54		2306	2071		Moving easily, exploiting leads 50-200m wide
55	90/08/06	0003	2125	133	Floes are becoming larger, some weathered ridges approaching hummocks
56		0102	2181		Ice conditions
57		0201	2212		"
58		0300	2242	136	Approaching 9+/10 coverage, more extensive ridging and rubble
59		0400	2257	137	Small and medium sized floes, mainly level ice with ridges around perimeter; no new ice has been seen forming in open water to date
60		0500	2289		Following leads; a few small hummocks are seen
61		0803	2347		Ice conditions

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
62		0900	2354	145	New ice now forming on some melt ponds; fresh rubble is average 1m height, approaching 2m; negotiating small and medium floes while to either side lie big and vast multi-year ice floes
63		0915			Entering big floe keeping steady speed; views of 1.5 to 2.5m thick ice turning alongside; track with centre initially free of ice but filling in from sides
64		0931	2460		Ice conditions
65		1020	2493		Moving slowly through a big floe; cracking in surrounding is confined to about 5m of ship sides
66		1029	2568		Views over bow rail of cusp formation; much of this rubble was grey-white ice at time of formation
67		1045	2643		Ram cycle; ship reverses about 150m; port and centre screws placed in reverse, starboard screw full ahead; break out of channel at about 45^0 to port towards a couple of small leads; up to about 4 knots in some 30 seconds and continue steady rate of advance
68		1102	2700		Ice conditions

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
69		1155	2750		Swing to port after slowing in vast floe, proceed around floe through lighter ice conditions; some grease ice forming in open water leads
70		1158	2783	149	Celebration with King Neptune
71		1800	3053		Ice conditions
72		2205	3073		"
73	90/08/07	0010	3083		"
74		0302	3093		"
75		0600	3109		Following leads up to 100m wide between big multi-year ice floes; helicopter down on ice ahead waiting for ship - it is staying close due to fog - lifts off and continues ahead
76		0712	3132	165	Helicopter has landed on ice beside ship due to mechanical difficulties, and disembarked ship's hydrologist; attempts to lift off and return to ship, without success; shuts down for repairs
77		1008	3149		Ice conditions
78		1108	3159		"
79		1155	3166		"
80		1309	3185		"
81		1406	3195		"
82		1455	3206		"
83		1656	3209		"

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
84		2200	3227		"
85		2303	3246		"
86	90/08/08	0207	3254		"
87		0220	3261		Media crew on big multi-year floe to film ship passing by
88		0314	3284	183	Large melt ponds, some approaching 100m across; extensive fracturing through the ice
89		0601	3297		Ice conditions
90		0653	3311		"
91		0755	3334		"
92		0807	3343	188	Approaching geographic North Pole; tourists gather around GPS receiver; Satnav display mounted to deckhead; 3rd officer calling position form GPS to Captain; ceremony and activities at the North Pole
93		2142	3631		Ice conditions
94		2208	3635		"
95		2303	3654	192	"
96	90/08/09	0001	3660		"
97		0104	3674	194	"
98		0206	3689		Following meandering broken channel
99		0310	3711	196	Ice conditions
100		0501	3727		"
101		0608		199	"

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
102		0704	3735		"
103		0801	3737		"
104		0916	3745	203	"
105		1011	3764		"
106		1103	3781		"; helicopter flying in fog
107		1205	3799		"
108		1317	3823		"
109		1431	3844		"
110		1459	3855		"
111		1652	3863		"
112		1710	3869		Very close pack conditions
113		1800	3877		Reverse in 9+/10 as speed drops below 2 knots; centre and port screws ahead, starboard in reverse to turn to starboard; follow a short lead
114		2101	3935	214	Ice conditions
115		2206	3944		Breaking through mostly small and medium floes; helicopter approaches to refuel; large open lead astern of vessel
116		2309	3957	216	Ice conditions
117	90/08/10	0020	3965		"
118		0102	3975		"
119		0152	3986		"

Appendix C (continued)

VHS Video Log

Segment Number	Chronology Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Description Reference Log Event Number	Supplementary Comments
120		0300	3990	220	About 20% of open water is covered by grease ice; following lead amongst 8/10 medium and big floe multi-year ice in improved visibility; lead pinches off in several places and ship follows, deflecting from side to side when pushed over by floe edges
121		0322	4049		Track is mostly open water through 8/10 total ice cover
122		0503	4046		Mainly small floe and ice cake
123		0603	4072		Back into medium and biog floes with large leads often more than 500m wide
124		0905	4090		Ice conditions
125		1027	4100		"
126		1103	4109		"
127		1207	4112		"
128		1304	4119		"
129		1404	4129		"
130		1600	4137		Breaking through a big floe at an average speed of about 3 knots; speed varies as cracks propagate ahead of vessel

Appendix C (continued)

VHS Video Log

Segment Number	Chronology Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Description Reference Log Event Number	Supplementary Comments
131		1730	4190		Most ridging formed at grey-white to thin first-year ice stage; thin crusty snow cover about 10-20cm
132		1853	4208		A few thaw holes now being seen
133		2000	4214		Track is weaving and full of brash and small pieces; fracturing alongside
134		2202	4231		Ice conditions
135		2303	4241		Lead about 400m wide
136	90/08/11	0005	4244		Ice conditions
137		0103	4256		"
138		0156	4266		"
139	90/08/04	0800	4272		Main engine control room; filming stopped before camera can swing to reactor control stations
140			4286		1 MW reserve diesel generator for auxiliary ship power
141			4307		Diesel generator start-up system
142			4312		Steam circuit piping and throttle valves
143			4324		Steam turbine room; zoom across to AC/DC rectifiers
144			4360		AC generators located below rectifiers
145			4374		AC generators
146			4378		200 kW emergency diesel generators

Appendix C (continued)

VHS Video Log

Segment Number	Chronology			Description	
	Date (yy/mm/dd)	Time (GMT)	Tape Counter (m)	Reference Log Event Number	Supplementary Comments
147			4384		Primary loop heat exchanger
148			4398		Turbine steam condenser tanks, piping and boiler feed pump
149			4417		Air bubbler system piping
150			4422		Turbine steam condensers
151			4426		Desalination equipment (120 tonnes/day)
152			4434		Air bubbler system turbine compressors; hull framing
153			4447		Main thrust bearings and intermediate propeller shafts

Appendix D

35mm Photography

(included under separate cover)

Appendix E

Trafficability Analysis by Route Segments

Appendix E

Trafficability Analysis by Route Segments

List of Tables

Table No.	Title
E.1	Trafficability Summary for Route Segment A
E.2	Trafficability Summary for Route Segment B
E.3	Trafficability Summary for Route Segment C
E.4	Trafficability Summary for Route Segment D
E.5	Trafficability Summary for Route Segment E
E.6	Trafficability Summary for Route Segment F
E.7	Trafficability Summary for Route Segment G
E.8	Trafficability Summary for Route Segment H
E.9	Trafficability Summary for Route Segment I
E.10	Trafficability Summary for Route Segment J
E.11	Trafficability Summary for Route Segment K
E.12	Trafficability Summary for Route Segment L
E.13	Trafficability Summary for Route Segment M
E.14	Trafficability Summary for Route Segment N

List of Plates

Plate No.	Title
E-1	Typical Ice Conditions in Route Segment A 0700 hrs August 2, 1990
E-2	Typical Ice Conditions in Route Segment B 2000 hrs August 2, 1990
E-3	Typical Ice Conditions in Route Segment C 0332 hrs August 4, 1990
E-4	Typical Ice Conditions in Route Segment D 1500 hrs August 5, 1990
E-5	Typical Ice Conditions in Route Segment E 0407 hrs August 6, 1990
E-6	Typical Ice Conditions in Route Segment F 1700 hrs August 6, 1990
E-7	Typical Ice Conditions in Route Segment G 1100 hrs August 7, 1990
E-8	Typical Ice Conditions in Route Segment H 0700 hrs August 8, 1990
E-9	Typical Ice Conditions in Route Segment I 0600 hrs August 9, 1990
E-10	Typical Ice Conditions in Route Segment J 1500 hrs August 9, 1990
E-11	Typical Ice Conditions in Route Segment K 0700 hrs August 10, 1990
E-12	Typical Ice Conditions in Route Segment L 1500 hrs August 10, 1990
E-13	Typical Ice Conditions in Route Segment M 2200 hrs August 10, 1990
E-14	Typical Ice Conditions in Route Segment N 0100 hrs August 11, 1990

Plate E-1 Typical Ice Conditions in Route Segment A
0700 hrs August 2, 1990

Table E.1

Trafficability Summary for Route Segment No. A

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/02	90/08/02
	Time (GMT)	0501	0700
	Latitude (N)	76°33'	76°41'
	Longitude (E)	69°05'	70°55'
	Total CMG (°true)	126°	
	Total DMG (n. mi.)	28.	
	Total Time (Hrs)	2.0	
	Notes:	Second reactor on stand-by	

II	METEOROLOGY	Knots	% Time
	Winds	CALM	N/A
	NE quadrant		
	SE quadrant		
	SW quadrant		
	NW quadrant		
	Dry Bulb Air Temperature (°C)	N/A	
	Visibility (n.mi.)		
	0 - 1/2:	0.	
	>1/2 - 6:	0.	
	>6:	100.	
	DARK:	0.	
	Precipitation	Nil	

III	ICE CONDITIONS	Tenths	Strips & Patches		
	Total Concentration	6-9			
	Partial Multi-Year				
	Partial Second-Year				
	Partial First-Year	6-9			
	Predominant Floe Size (m)	< 20			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	18.	10.	25.	2.
	Thaw Holes (%)	5.	0.	10.	2.
	Ridging and Rubble (%)	55.	20.	90.	2.
	Ice Thickness (cm)	N/A (extensive rafting)			
	Ice Convergence, Pressure	Nil			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	100.
		PUSH:	0.
		BREAK:	0.
		OTHER:	0.
	Manoeuvres		Ice Avoidance

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	55.0	55.	55.	2
	Combinator (0-20)	19.0	19.	19.	2
	Propeller Speed (rpm)	145.0	145.0	145.0	2
	On-Hour Ship Speed (knots)	16.5	14.	19.	2
	Hourly SMG (knots)	15.0	11.	19.	2

Plate E-2 Typical Ice Conditions in Route Segment B
2000 hrs August 2, 1990

Table E.2

Trafficability Summary for Route Segment No. 8

		Begin	End
I	TRANSIT PARTICULARS		
	Date (yy/mm/dd)	90/08/02	90/08/03
	Time (GMT)	0701	1500
	Latitude (N)	76°41'	75°50'
	Longitude (E)	70°55'	89°46'
	Total CMG (°true)	94°	
	Total DMG (n. mi.)	280.	
	Total Time (Hrs)	32.	
	Notes:	Much of period spent alongside convoy; 2 hr period shut down	

		Knots	% Time
II	METEOROLOGY		
	Winds	CALM	N/A
	NE quadrant		
	SE quadrant		
	SW quadrant		
	NW quadrant		
	Dry Bulb Air Temperature (°C)	+0.8	
	Visibility (n.mi.)		
	0 - 1/2:	0.	
	>1/2 - 6:	0.	
	>6:	100.	
	DARK:	0.	
	Precipitation	occasional patches of light snow	

		Tenths	Strips & Patches
III	ICE CONDITIONS		
	Total Concentration	0-3	6-9
	Partial Multi-Year		
	Partial Second-Year		
	Partial First-Year	0-3	6-9
	Predominant Floe Size (m)	< 100	

	Average	Minimum	Maximum	Sample size
Melt Ponds (%)	46.	25.	70.	7.
Thaw Holes (%)	19.	5.	30.	7.
Ridging and Rubble (%)	1.	0.	5.	7.

Ice Thickness (cm)	N/A (generally <150 cm)
Ice Convergence, Pressure	Nil

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	88.
		PUSH:	10.
		BREAK:	2.
		OTHER:	0.
	Manoeuvres		Variable speeds alongside convoy

		Average	Minimum	Maximum	Sample Size
V	VESSEL PERFORMANCE				
	Reactor power (%)	55.0	55.	55.	25
	Combinator (0-20)	16.2	6.	20.	25
	Propeller Speed (rpm)	126.0	53.3	151.7	25
	On-Hour Ship Speed (knots)	16.6	0.	20.	25
	Hourly SMG (knots)	15.0	7.	20.	23

Plate E-3 Typical Ice Conditions in Route Segment C
0332 hrs August 4, 1990

Table E.3

Trafficability Summary for Route Segment No. C

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/03	90/08/05
	Time (GMT)	1601	0400
	Latitude (N)	75°55'	80°11'
	Longitude (E)	90°34'	99°58'
	Total CMG (°true)	21°	
	Total DMG (n. mi.)	310.	
	Total Time (Hrs)	36.	
	Notes:	Air bubbler system turned on; following shorefast ice edge	

II	METEOROLOGY	Knots	% Time
	Winds	CALM	0
	NE quadrant	15.4	100
	SE quadrant		0
	SW quadrant		0
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	+4.0	
	Visibility (n.mi.)		
	0 - 1/2:	0.	
	>1/2 - 6:	3.	
	>6:	97.	
	DARK:	0.	
	Precipitation	occasional light drizzle	

III	ICE CONDITIONS	Tenths	Strips & Patches		
	Total Concentration	8-10			
	Partial Multi-Year				
	Partial Second-Year	4-5			
	Partial First-Year	4-5			
	Predominant Floe Size (m)	> 20 up to fast ice			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	39.	20.	70.	29.
	Thaw Holes (%)	8.	5.	20.	29.
	Ridging and Rubble (%)	15.	0.	60.	29.
	Ice Thickness (cm)	128	100	170	6
	Ice Convergence, Pressure	Nil			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	29.
		PUSH:	18.
		BREAK:	52.
		OTHER:	1.
	Manoeuvres		Exploiting leads and old track

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	64.1	55.	90.	32
	Combinator (0-20)	18.8	12.	20.	32
	Propeller Speed (rpm)	114.0	80.0	143.3	32
	On-Hour Ship Speed (knots)	14.5	8.	19.	32
	Hourly SMG (knots)	13.5	6.	19.	27

Plate E-4 Typical Ice Conditions in Route Segment D
1500 hrs August 5, 1990

Table E.4

Trafficability Summary for Route Segment No. D

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/05	90/08/05
	Time (GMT)	1401	2200
	Latitude (N)	81°26'	82°51'
	Longitude (E)	95°37'	96°18'
	Total CMG (°true)	353°	
	Total DMG (n. mi.)	100.	
	Total Time (Hrs)	8.0	
	Notes:	Increasing ridging and rubble, majority is 1-2m sail heights, about 30% is fresh and unconsolidated	

II	METEOROLOGY	Knots	% Time
	Winds	CALM	0
	NE quadrant	16.1	100
	SE quadrant		0
	SW quadrant		0
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	+2.6	
	Visibility (n.mi.)		
	0 - 1/2:	0.	
	>1/2 - 6:	0.	
	>6:	100.	
	DARK:	0.	
	Precipitation	Nil	

III	ICE CONDITIONS	Tenths	Strips & Patches
	Total Concentration	9	
	Partial Multi-Year	8	
	Partial Second-Year		
	Partial First-Year	1	
	Predominant Floe Size (m)	< 100	

	Average	Minimum	Maximum	Sample size
Melt Ponds (%)	20.	15.	30.	7.
Thaw Holes (%)	0.	0.	0.	7.
Ridging and Rubble (%)	62.	30.	80.	7.
Ice Thickness (cm)	159	120	200	6
Ice Convergence, Pressure	Nil			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	7.
		PUSH:	9.
		BREAK:	75.
		OTHER:	9.
	Manoeuvres		Occasional rams in heavy ridging within larger floes

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	90.0	90.	90.	7
	Combinator (0-20)	19.7	18.	20.	7
	Propeller Speed (rpm)	145.0	141.7	153.3	7
	On-Hour Ship Speed (knots)	12.7	8.	15.	7
	Hourly SMG (knots)	11.5	7.	14.	6

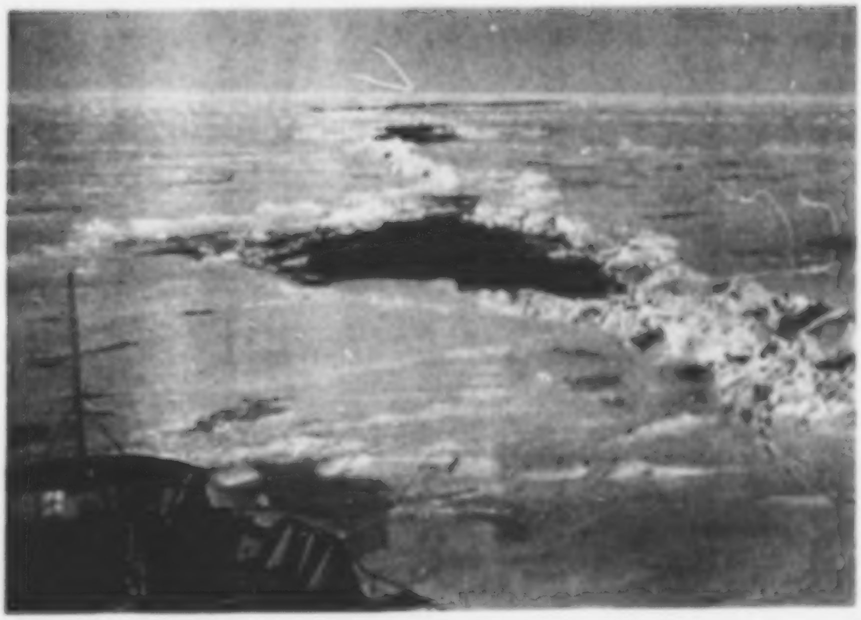

Plate E-5 Typical Ice Conditions in Route Segment E
0407 hrs August 6, 1990

Table E.5

Trafficability Summary for Route Segment No. E

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/05	90/08/06
	Time (GMT)	2201	0800
	Latitude (N)	82°51'	84°14'
	Longitude (E)	96°18'	100°55'
	Total CMG (°true)	021°	
	Total DMG (n. mi.)	87.	
	Total Time (Hrs)	10.0	
	Notes:	Extensive rafting up to 3 layers thick	

II	METEOROLOGY	Knots	% Time
	Winds	CALM	0
	NE quadrant	18.	90
	SE quadrant	19.	10
	SW quadrant		0
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	+3.4	
	Visibility (n.mi.)		
	0 - 1/2:	0.	
	>1/2 - 6:	20.	
	>6:	80.	
	DARK:	0.	
	Precipitation	Fog develops last 3 hours of route segment	

III	ICE CONDITIONS	Tenths	Strips & Patches
	Total Concentration	9	
	Partial Multi-Year	9	
	Partial Second-Year		
	Partial First-Year		
	Predominant Floe Size (m)	≤ 100	

	Average	Minimum	Maximum	Sample size
Melt Ponds (%)	17.	5.	25.	10.
Thaw Holes (%)	0.	0.	1.	10.
Ridging and Rubble (%)	13.	5.	40.	10.
Ice Thickness (cm)	163	110	240	8
Ice Convergence, Pressure	Some convergence, light pressure beginning to build			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	2.
		PUSH:	4.
		BREAK:	92.
		OTHER:	2.
	Manoeuvres		

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	92.0	90.	100.	10
	Combinator (0-20)	20.0	20.	20.	10
	Propeller Speed (rpm)	137.0	123.3	150.0	10
	On-Hour Ship Speed (knots)	11.1	3.	15.	10
	Hourly SMG (knots)	9.5	7.	11.	9

Plate E-6 Typical Ice Conditions in Route Segment F
1700 hrs August 6, 1990

Table E.6

Trafficability Summary for Route Segment No. F

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/06	90/08/06
	Time (GMT)	0801	2200
	Latitude (N)	84°14'	85°27'
	Longitude (E)	100°55'	92°21'
	Total CMG (°True)	339°	
	Total DMG (n. mi.)	90.	
	Total Time (Hrs)	14	
	Notes:	Includes 3 hour stop for social activity	

II	METEOROLOGY	Knots	% Time
	Winds	CALM	0
	NE quadrant	11.	100
	SE quadrant		0
	SW quadrant		0
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	+1.2	
	Visibility (n.mi.)		
	0 - 1/2:	0.	
	>1/2 - 6:	45.	
	>6:	55.	
	DARK:	0.	
	Precipitation	Fog during first 5 hrs of route segment	

III	ICE CONDITIONS	Tenths	Strips & Patches		
	Total Concentration	9-9+			
	Partial Multi-Year	9-9+			
	Partial Second-Year				
	Partial First-Year				
	Predominant Floe Size (m)	≤ 500			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	19.	15.	20.	11.
	Thaw Holes (%)	0.	0.	0.	11.
	Ridging and Rubble (%)	17.	10.	30.	11.
	Ice Thickness (cm)	190	165	230	7
	Ice Convergence, Pressure	Moderate pressure throughout segment			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	0.
		PUSH:	1.
		BREAK:	95.
		OTHER:	4.
	Manoeuvres		

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	100.0	100.	100.	11
	Combinator (0-20)	17.4	12.7	20.	11
	Propeller Speed (rpm)	140.0	130.0	153.3	11
	One-Hour Ship Speed (knots)	10.9	7.	14.	11
	Hourly SMG (knots)	9.1	5.	13.	9

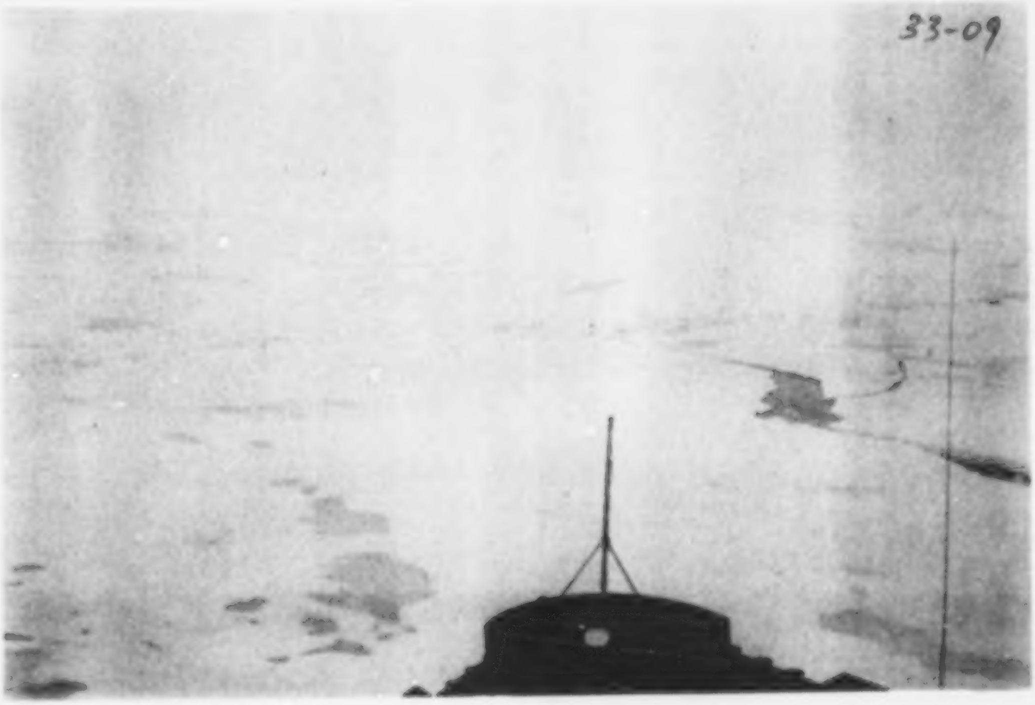

Plate E-7 Typical Ice Conditions in Route Segment G
1100 hrs August 7, 1990

Table E.7

Trafficability Summary for Route Segment No. G

		Begin	End		
I	TRANSIT PARTICULARS				
	Date (yy/mm/dd)	90/08/06	90/08/07		
	Time (GMT)	2301	1900		
	Latitude (N)	85°39'	86°10'		
	Longitude (E)	92°39'	95°13'		
	Total CMG (°true)	000°			
	Total DMG (n. mi.)	155.			
	Total Time (Hrs)	20			
	Notes:	Includes 2 hour stop to repair helicopter			

		Knots	% Time
II	METEOROLOGY		
	Winds	CALM	0
	NE quadrant	22.	94
	SE quadrant	23.	6
	SW quadrant		0
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	+1.2	
	Visibility (n.mi.)		
	0 - 1/2:	18	
	>1/2 - 6:	65.	
	>6:	17.	
	DARK:	0.	
	Precipitation	Extensive fog and occasional rain	

		Tenths	Strips & Patches		
III	ICE CONDITIONS				
	Total Concentration	9-9+			
	Partial Multi-Year	9-9+			
	Partial Second-Year				
	Partial First-Year				
	Predominant Floe Size (m)	≤ 500			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	20.	15.	30.	17.
	Thaw Holes (%)	0.	0.	0.	17.
	Ridging and Rubble (%)	7.	5.	10.	17.
	Ice Thickness (cm)	207	160	275	9
	Ice Convergence, Pressure	Moderate pressure builds during latter portion of segment			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	3.
		PUSH:	0.
		BREAK:	94.
		OTHER:	3.
	Manoeuvres		

		Average	Minimum	Maximum	Sample Size
V	VESSEL PERFORMANCE				
	Reactor Power (%)	100.	100.	100.	17
	Combinator (0-20)	19.8	16.7	20.0	17
	Propeller Speed (rpm)	146.3	126.7	153.3	17
	On-Hour Ship Speed (knots)	10.1	2.	15.	17
	Hourly SMG (knots)	9.2	5.	12.	14

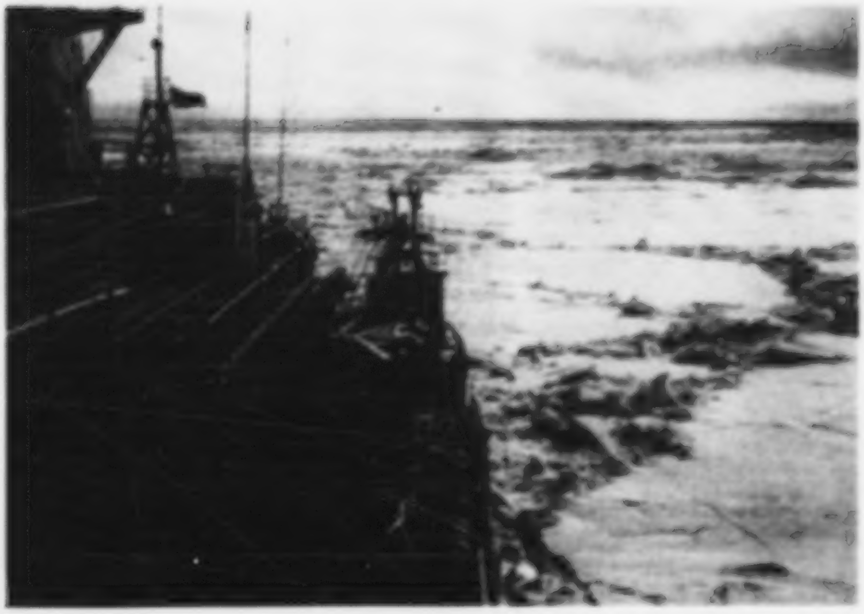

Plate E-8 Typical Ice Conditions in Route Segment H
0700 hrs August 8, 1990

Table E 8

Trafficability Summary for Route Segment No. H

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/07	90/08/08
	Time (GMT)	1901	0700
	Latitude (N)	88°10'	89°46'
	Longitude (E)	95°13'	102°24'
	Total CMG (°true)	002°	
	Total DMG (n. mi.)	92.	
	Total Time (Hrs)	12	
	Notes:	Mix of fresh and older ridges reach 3m sail height	

II	METEOROLOGY		Knots	% Time
	Winds		CALM	0
	NE quadrant			0
	SE quadrant		23.	100
	SW quadrant			0
	NW quadrant			0
	Dry Bulb Air Temperature (°C)		+1.4	
	Visibility (n.mi.)			
		0 - 1/2:	0.	
		>1/2 - 6:	0.	
		>6:	100.	
		DARK:	0.	
	Precipitation	Rain		

III	ICE CONDITIONS	Tenths	Strips & Patches		
	Total Concentration	9+			
	Partial Multi-Year	9+			
	Partial Second-Year				
	Partial First-Year				
	Predominant Floe Size (m)	20 - 500 m			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	16.	5.	25.	10.
	Thaw Holes (%)	0.	0.	0.	10.
	Ridging and Rubble (%)	16.	5.	25.	10.
	Ice Thickness (cm)	209	165	300	6
	Ice Convergence, Pressure	Moderate pressure, significant new ridging			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	0.
		PUSH:	0.
		BREAK:	88.
		OTHER:	12.
	Manoeuvres		Occasional rams

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	100.0	100.	100.	10
	Combinator (0-20)	20.0	20.	20.	10
	Propeller Speed (rpm)	150.	150.	150.	10
	On-Hour Ship Speed (knots)	9.6	3.	14.	10
	Hourly SMG (knots)	8.1	4.	12.	7

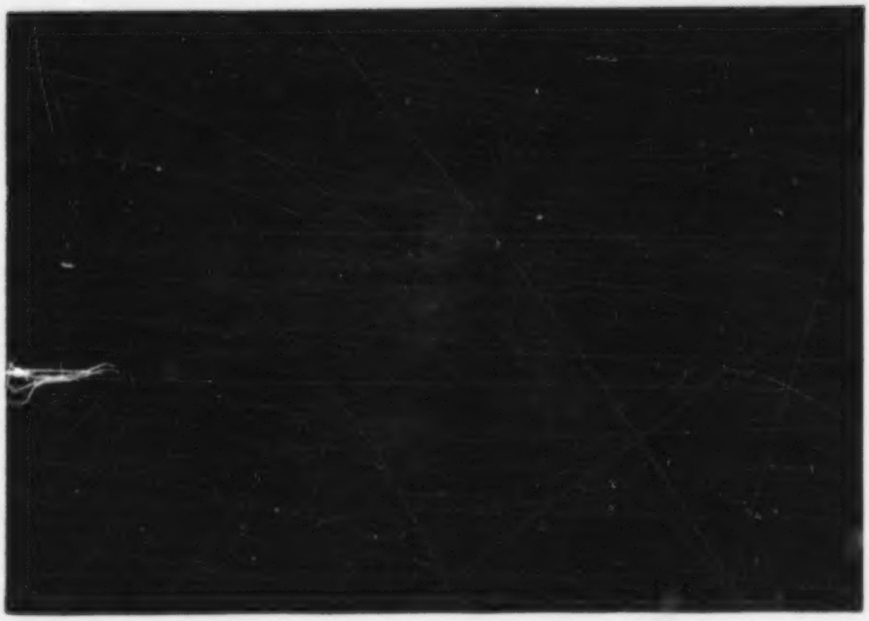

Plate E-9 Typical Ice Conditions in Route Segment I
0600 hrs August 9, 1990

Table E.9

Trafficability Summary for Route Segment No. 1

I	TRANSIT PARTICULARS	Begin	End		
	Date (yy/mm/dd)	90/08/09	90/08/09		
	Time (GMT)	0001	1100		
	Latitude (N)	89°50'	88°10'		
	Longitude (E)	112°28'	93°43'		
	Total CMG (°true)	176°			
	Total DMG (n. mi.)	120.			
	Total Time (Hrs)	11.0			
	Notes:	Following inbound track, gradually more time breaking fresh ice			
II	METEOROLOGY	Knots	% Time		
	Winds	CALM	0		
	NE quadrant	33	27		
	SE quadrant		0		
	SW quadrant	26	55		
	NW quadrant	27	18		
	Dry Bulb Air Temperature (°C)				
	Visibility (n.mi.)				
	0 - 1/2:	0.			
	>1/2 - 6:	0.			
	>6:	100.			
	DARK:	0.			
	Precipitation	Nil			
III	ICE CONDITIONS	Tenths	Strips & Patches		
	Total Concentration	9			
	Partial Multi-Year	9			
	Partial Second-Year				
	Partial First-Year				
	Predominant Floe Size (m)	20 - 500 m			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	16.	10.	25.	11.
	Thaw Holes (%)	0.	0.	0.	11.
	Ridging and Rubble (%)	14.	5.	20.	11.
	Ice Thickness (cm)	207	185	250	5
	Ice Convergence, Pressure	Nil			
IV	TACTICAL NAVIGATION				
	Transit Mode (%) OPEN:	1.			
	PUSH:	79.			
	BREAK:	19.			
	OTHER:	1.			
	Manoeuvres	Guided by old track, occasionally break ice where track has shifted			
V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	95.5	90.	100.	11
	Combinator (0-20)	20.0	20.	20.	11
	Propeller Speed (rpm)	149.7	136.7	160.	11
	On-Hour Ship Speed (knots)	12.2	6.	15.	11
	Hourly SMG (knots)	9.7	6.	13.	11

Plate E-10 Typical Ice Conditions in Route Segment J
1500 hrs August 9, 1990

Table E.10

Trafficability Summary for Route Segment No. J

		Begin	End
I	TRANSIT PARTICULARS		
	Date (yy/mm/dd)	90/08/09	90/08/09
	Time (GMT)	1101	2200
	Latitude (N)	88°10'	86°45'
	Longitude (E)	93°43'	73°51'
	Total CMG (°true)	224°	
	Total DMG (n. mi.)	100.	
	Total Time (Hrs)	11.0	
	Notes:	Leads becoming more frequent.	

		Knots	% Time
II	METEOROLOGY		
	Winds	CALM	0
	NE quadrant		0
	SE quadrant	24	11
	SW quadrant	20	89
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	+1.8	
	Visibility (n.mi.)		
	0 - 1/2:	11.	
	>1/2 - 6:	11.	
	>6:	78.	
	DARK:	0.	
	Precipitation	Fog patches	

		Tenths	Strips & Patches
III	ICE CONDITIONS		
	Total Concentration	9	
	Partial Multi-Year	9	
	Partial Second-Year		
	Partial First-Year		
	Predominant Floe Size (m)	20 - 500 m	

	Average	Minimum	Maximum	Sample size
Melt Ponds (%)	22.	10.	30.	9.
Thaw Holes (%)	0.	0.	0.	9.
Ridging and Rubble (%)	18.	10.	25.	9.
Ice Thickness (cm)	198	170	230	9.
Ice Convergence, Pressure	Nil			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	8.
		PUSH:	4.
		BREAK:	88.
		OTHER:	C.
	Manoeuvres		Exploit leads where possible

		Average	Minimum	Maximum	Sample Size
V	VESSEL PERFORMANCE				
	Reactor Power (%)	100.0	100.	100.	9
	Combinator (0-20)	20.0	20.	20.	9
	Propeller Speed (rpm)	135.6	116.7	146.7	9
	On-Hour Ship Speed (knots)	11.6	9.	13.	9
	Hourly SMG (knots)	10.3	7.	14.	7

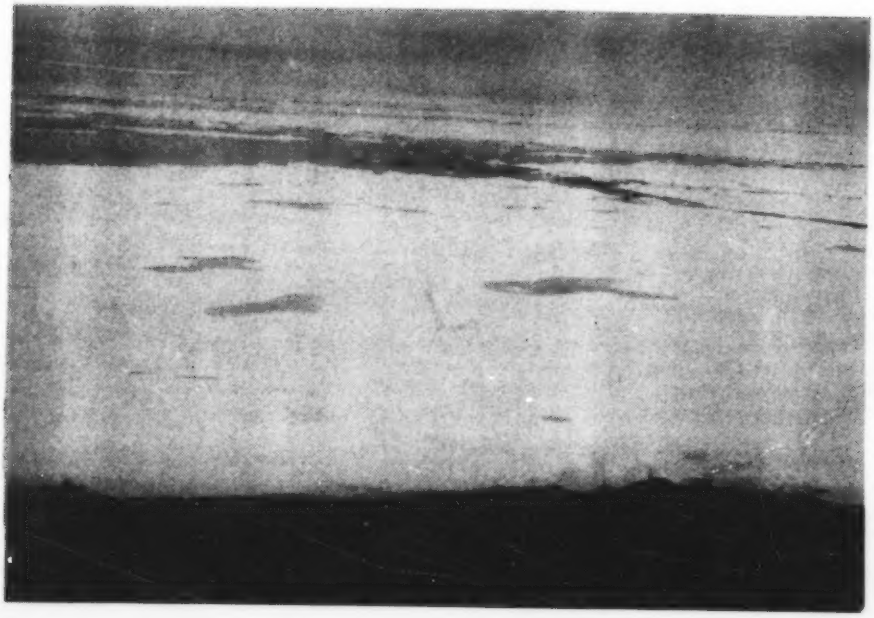

Plate E-11 Typical Ice Conditions in Route Segment K
0700 hrs August 10, 1990

Table E.11

Trafficability Summary for Route Segment No. K

I TRANSIT PARTICULARS

	Begin	End
Date (yy/mm/dd)	90/08/09	90/08/10
Time (GMT)	2201	1400
Latitude (N)	86°45'	83°52'
Longitude (E)	73°51'	65°50'
Total CMG (°true)	197°	
Total DMG (n. mi.)	167.	
Total Time (Hrs)	16.0	
Notes:	Many favourably oriented leads.	

II METEOROLOGY

	Knots	% Time
Winds	CALM	0
NE quadrant		0
SE quadrant	18	75
SW quadrant	14	25
NW quadrant		0
Dry Bulb Air Temperature (°C)	+2.0	
Visibility (n.mi.)		
0 - 1/2:	0.	
>1/2 - 6:	13.	
>6:	87.	
DARK:	0.	
Precipitation	Occasional fog patches	

III ICE CONDITIONS

	Tenths	Strips & Patches
Total Concentration	8-9	
Partial Multi-Year	8-9	
Partial Second-Year		
Partial First-Year		
Predominant Floe Size (m)	≤ 500 m	

	Average	Minimum	Maximum	Sample size
Melt Ponds (%)	20.	10.	30.	16.
Thaw Holes (%)	0.	0.	0.	16.
Ridging and Rubble (%)	11.	5.	30.	16.
Ice Thickness (cm)	185	120	340	11.
Ice Convergence, Pressure	Nil			

IV TACTICAL NAVIGATION

Transit Mode (%)	OPEN:	41.
	PUSH:	8.
	BREAK:	51.
	OTHER:	0.
Manoeuvres		Following leads extensively

V VESSEL PERFORMANCE

	Average	Minimum	Maximum	Sample Size
Reactor Power (%)	91.2	90.	100.	16
Combinator (0-20)	15.6	8.3	20.	16
Propeller Speed (rpm)	135.0	113.3	153.3	16
On-Hour Ship Speed (knots)	13.4	9.	20.	16
Hourly SMG (knots)	12.1	7.	17.	16

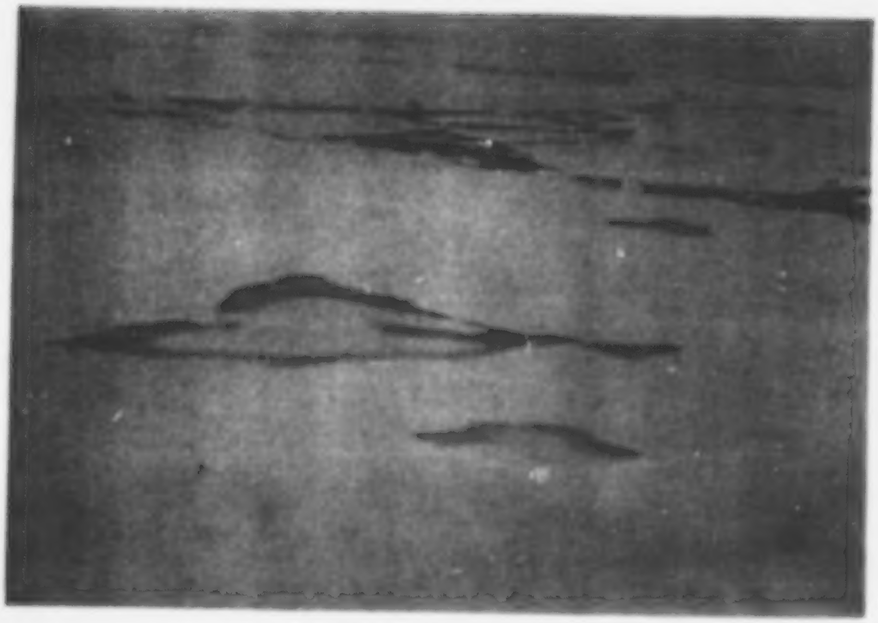

Plate E-12 Typical Ice Conditions in Route Segment L
1500 hrs August 10, 1990

Table E.12

Trafficability Summary for Route Segment No. L

I	TRANSIT PARTICULARS	Begin	End
	Date (yy/mm/dd)	90/08/10	90/08/10
	Time (GMT)	1401	2000
	Latitude (N)	83°52'	82°34'
	Longitude (E)	65°50'	65°58'
	Total CMG (°true)	177°	
	Total DMG (n. mi.)	88.	
	Total Time (Hrs)	6.	
	Notes:	Ice appears significantly weaker, fractures easily	

II	METEOROLOGY	Knots	% Time
	Winds	CALM	0
	NE quadrant		0
	SE quadrant	21	33
	SW quadrant	22	67
	NW quadrant		0
	Dry Bulb Air Temperature (°C)	-0.3	
	Visibility (n.mi.)		
	0 - 1/2:	17.	
	>1/2 - 6:	17.	
	>6:	66.	
	DARK:	0.	
	Precipitation	Fog ends early in this segment	

III	ICE CONDITIONS	Tenths	Strips & Patches
	Total Concentration	8-9	
	Partial Multi-Year		
	Partial Second-Year	8-9 (first-year interface @ 50cm)	
	Partial First-Year		
	Predominant Floe Size (m)	≤ 100	

		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	11.	5.	15.	6.
	Thaw Holes (%)	0.	0.	0.	6.
	Ridging and Rubble (%)	18.	10.	25.	6.
	Ice Thickness (cm)	210	170	250	2.
	Ice Convergence, Pressure	Nil			

IV	TACTICAL NAVIGATION		
	Transit Mode (%)	OPEN:	18.
		PUSH:	4.
		BREAK:	78.
		OTHER:	0.
	Manoeuvres	Steady course	

V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	90.0	90.	90.	6
	Combinator (0-20)	18.4	15.3	20.	6
	Propeller Speed (rpm)	148.9	146.7	150.7	6
	On-Hour Ship Speed (knots)	13.8	6.	18.	6
	Hourly SMG (knots)	13.0	9.	16.	6

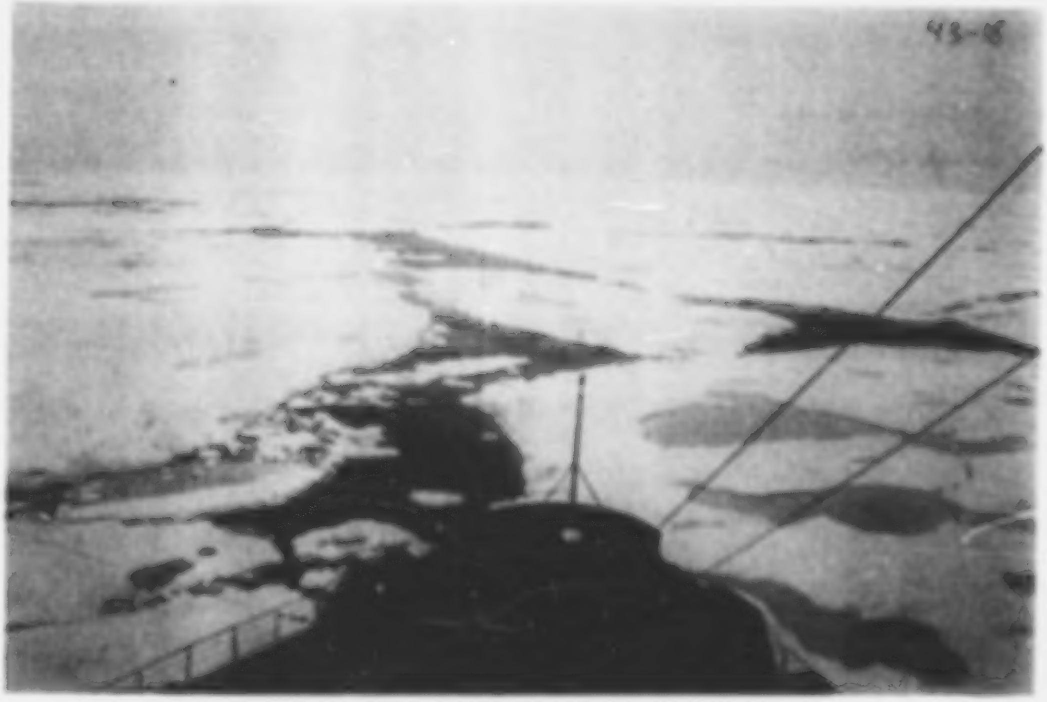

Plate E-13 Typical Ice Conditions in Route Segment M
2200 hrs August 10, 1990

Table E.13

Trafficability Summary for Route Segment No. M

I TRANSIT PARTICULARS

	Begin	End
Date (yy/mm/dd)	90/08/10	90/08/10
Time (GMT)	2001	2200
Latitude (N)	82°34'	82°07'
Longitude (E)	65°56'	65°29'
Total CMG (°true)	190°	
Total DMG (n. mi.)	22.	
Total Time (Hrs)	2.	

Notes: Most of segment involved breaking through a single vast floe

II METEOROLOGY

	Knots	% Time
Winds	CALM	0
NE quadrant		0
SE quadrant		0
SW quadrant	30	100
NW quadrant		0

Dry Bulb Air Temperature (°C)	+1.5
Visibility (n.mi.)	
0 - 1/2:	0.
>1/2 - 6:	0.
>6:	100.
DARK:	0.
Precipitation	Rain and fog

III ICE CONDITIONS

	Tenths	Strips & Patches
Total Concentration	9+	
Partial Multi-Year		
Partial Second-Year	9+	
Partial First-Year		
Predominant Floe Size (m)	500 - 2000	

	Average	Minimum	Maximum	Sample size
Melt Ponds (%)	25.	25.	25.	2.
Thaw Holes (%)	5.	5.	5.	2.
Ridging and Rubble (%)	15.	0.	30.	2.
Ice Thickness (cm)	115			1.
Ice Convergence, Pressure	Nil			

IV TACTICAL NAVIGATION

Transit Mode (%)	OPEN:	0.
	PUSH:	15.
	BREAK:	85.
	OTHER:	0.
Manoeuvres		Steady course

V VESSEL PERFORMANCE

	Average	Minimum	Maximum	Sample Size
Reactor Power (%)	90.0	90.	90.	2
Combinator (0-20)	17.7	15.3	20.	2
Propeller Speed (rpm)	156.7	156.7	156.7	2
On-Hour Ship Speed (knots)	16.5	16.	17.	2
Hourly SMG (knots)	13.5	13.	14.	2

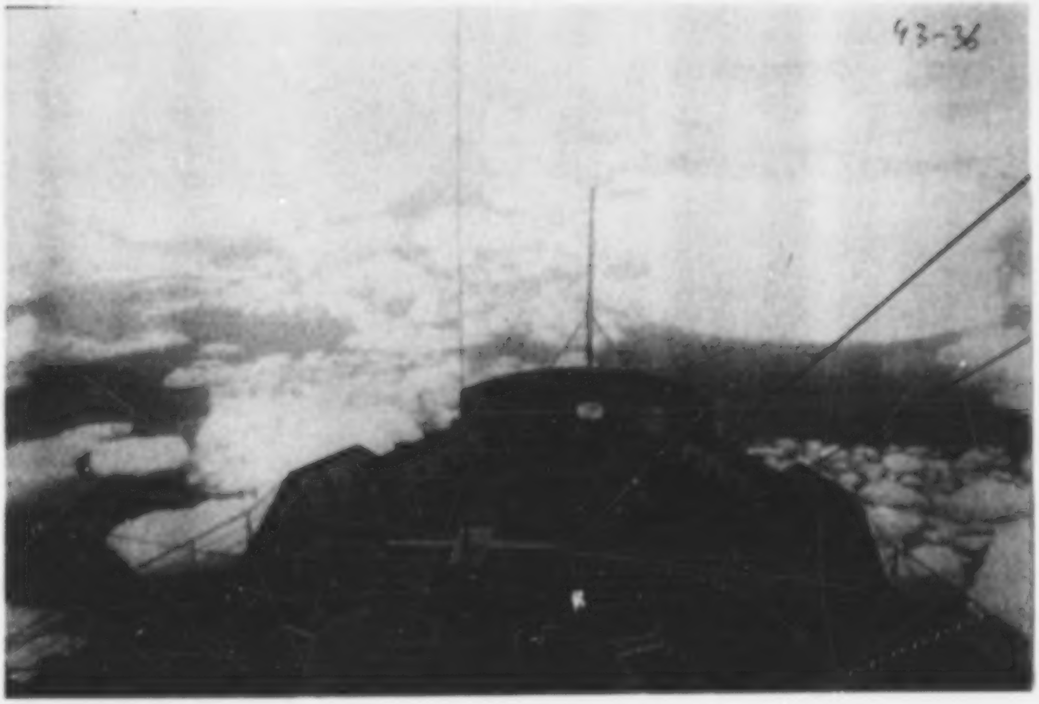

Plate E-14 Typical Ice Conditions in Route Segment N
0100 hrs August 11, 1990

Table E.14

Trafficability Summary for Route Segment No. N

I	TRANSIT PARTICULARS	Begin	End		
	Date (yy/mm/dd)	90/08/10	90/08/11		
	Time (GMT)	2201	0200		
	Latitude (N)	82°07'	81°11'		
	Longitude (E)	65°29'	65°49'		
	Total CMG (°true)	176°			
	Total DMG (n. mi.)	60.			
	Total Time (Hrs)	4.			
	Notes:	Pack ice with large open water areas			
II	METEOROLOGY	Knots	% Time		
	Winds	CALM	0		
	NE quadrant		0		
	SE quadrant		0		
	SW quadrant	26	100		
	NW quadrant		0		
	Dry Bulb Air Temperature (°C)	+1.6			
	Visibility (n.mi.)				
	0 - 1/2:	75.			
	>1/2 - 6:	0.			
	>6:	25.			
	DARK:	0.			
	Precipitation	Fog			
III	ICE CONDITIONS	Tenths	Strips & Patches		
	Total Concentration	7			
	Partial Multi-Year				
	Partial Second-Year	5			
	Partial First-Year	2			
	Predominant Floe Size (m)	≤ 500			
		Average	Minimum	Maximum	Sample size
	Melt Ponds (%)	28.	25.	30.	3.
	Thaw Holes (%)	8.	5.	10.	3.
	Ridging and Rubble (%)	9.	0.	15.	4.
	Ice Thickness (cm)	140	135	145	3.
	Ice Convergence, Pressure	Nil			
IV	TACTICAL NAVIGATION				
	Transit Mode (%) OPEN:	35.			
	PUSH:	5.			
	BREAK:	60.			
	OTHER:	0.			
	Manoeuvres	Steady course			
V	VESSEL PERFORMANCE	Average	Minimum	Maximum	Sample Size
	Reactor Power (%)	75.0	70.	90.	4
	Combinator (0-20)	20.0	20.	20.	4
	Propeller Speed (rpm)	156.7	156.7	156.7	4
	On-Hour Ship Speed (knots)	15.0	11.	17.	4
	Hourly SMG (knots)	14.0	6.	19.	4